The WELDING JOURNAL

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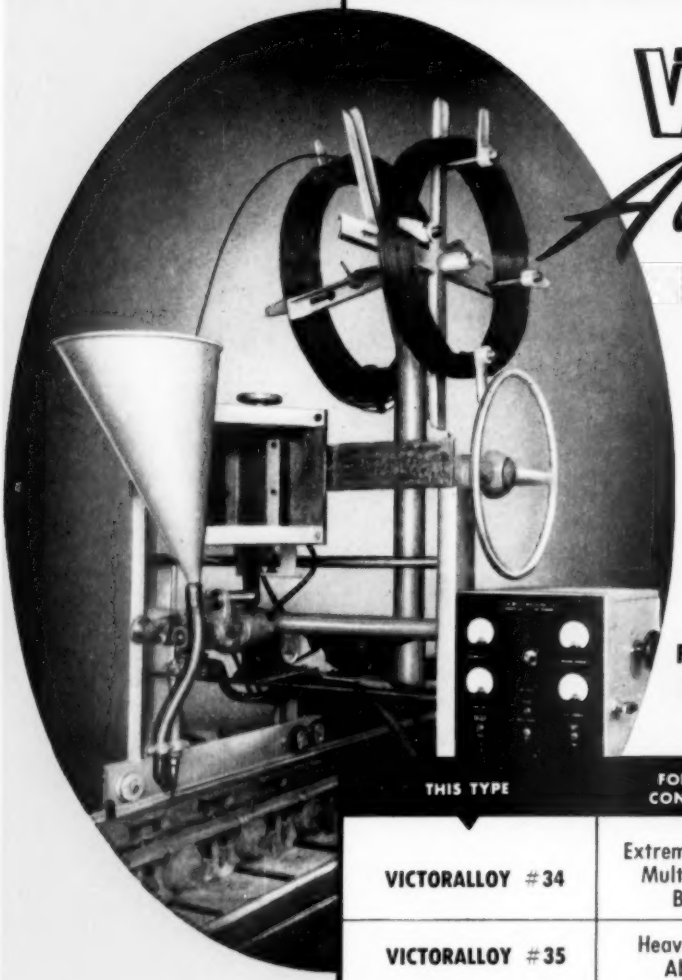

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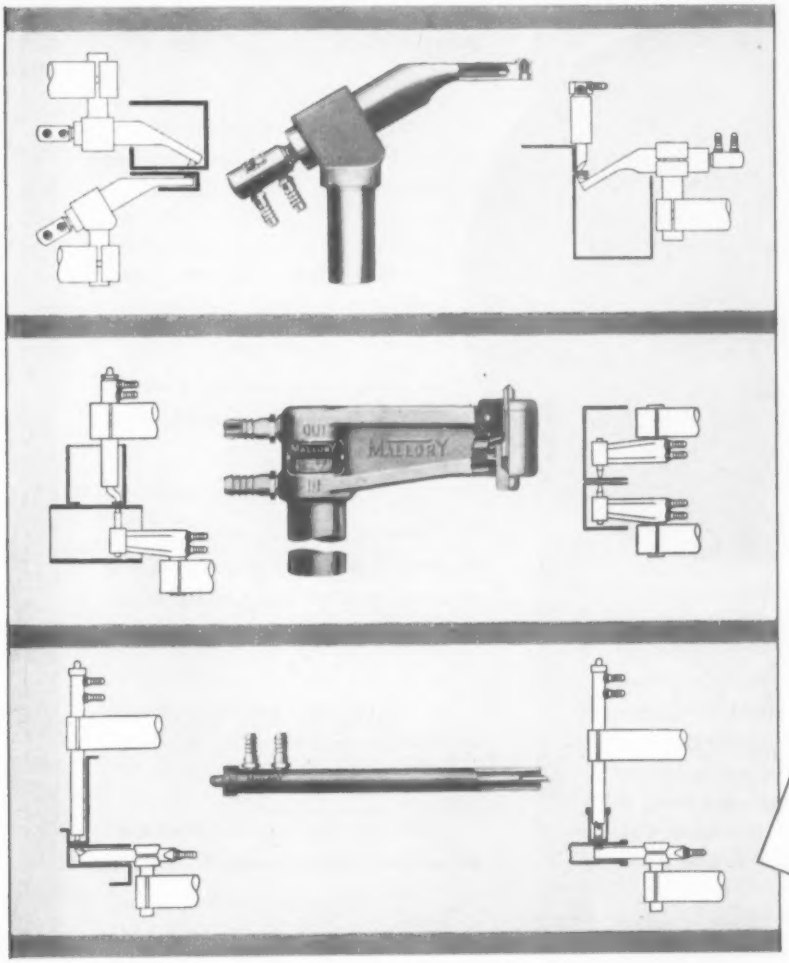

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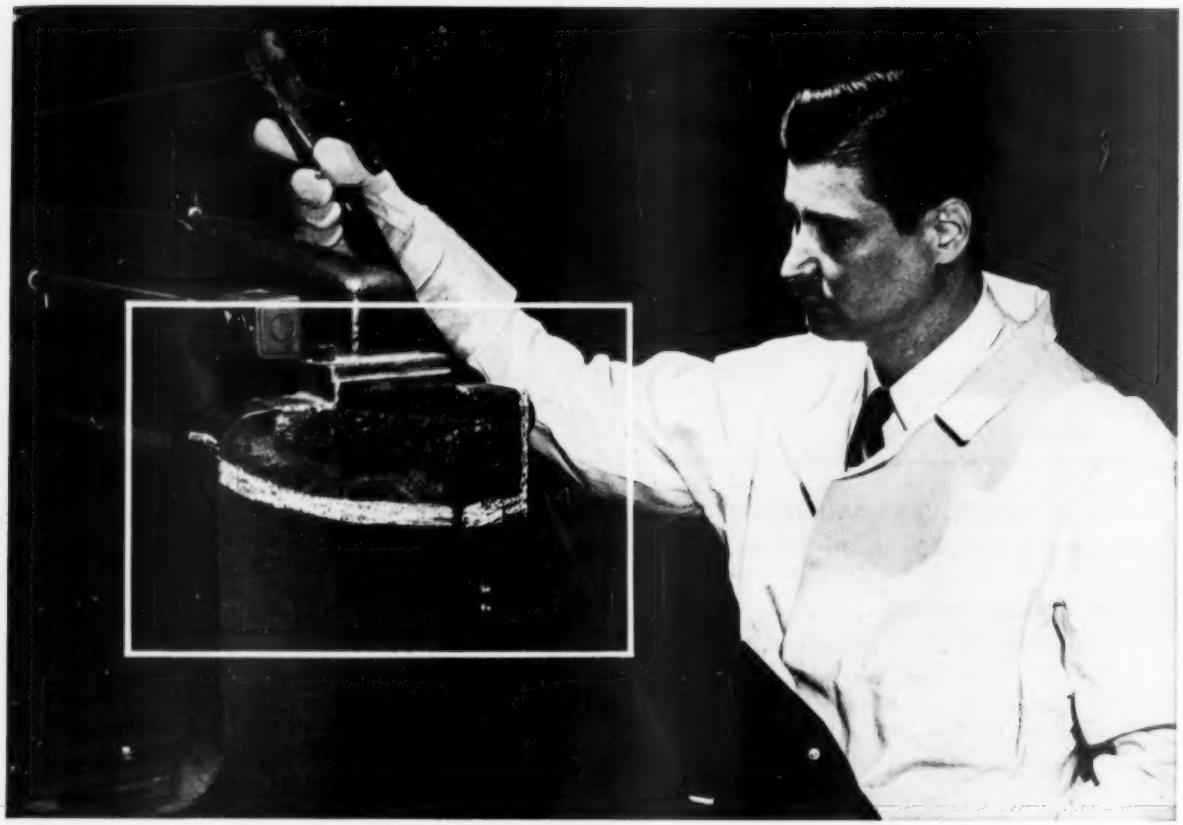

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Advanced Information for the Brazing Operator

Practical information on the brazing of different materials, fluxes and their limitations, design of joints and brazing alloys

by E. F. Davis

Abstract

The need for advanced brazing information in this era of complex designs and alloys is evident. A course on the subject has been devised and given to 100 men at the East Pittsburgh Plant of Westinghouse. The material in the course deals with information intended to guide the operator in his interpretation of specifications and manufacturing information written for his guidance.

With increased knowledge of the characteristics of the brazing materials, fluxes and alloys, which he is required to use, he will be less apt to deviate from that which is specified. He is given information regarding action of the flux, its possibilities and limitations, the melting points and flow points of alloys, and the reason for the plastic range of alloys. And most important, the metallurgical aspect of the formation of the joint.

BRAZING

TO THE casual observer, brazing appears to be a simple operation. The foreman or other persons in supervisory positions who select personnel for brazing operations, or specify the amount of operator training should not be misled by this apparent simplicity. Brazing is one of the most important joining processes and should be so treated. Personnel performing brazing operations should have the proper training to qualify for the work regardless of the form of heating.

A procedure for providing this training has been evolved and successfully applied. It may best be described by reviewing the experiences encountered with one shop operated class. While participants were experienced in production brazing operations, the first step was to review with them the fundamentals of brazing:

(*a*) Base metals composition.
(*b*) Cleaning requirements.
  1. Surface condition.
  2. Undesirable contamination.
(*c*) Capillarity.
  1. Cause.
  2. Effectiveness.
  3. Requirements.
(*d*) Design.
(*e*) Brazing alloys.
  1. Type.
  2. Wetting.
  3. Thermal and melting characteristics.
  4. Application.
(*f*) Fluxes.
  1. Type.
  2. Thermal characteristics.
  3. Application.
  4. Residue.
  5. Postcleaning.
(*g*) Heating methods.

This procedure was followed because it was found inadequate to simply tell an operator to perform some required function or not to perform it. The operator should be told why he does certain things and what results from not doing them properly.

BASE METALS

Base metal was listed as the most important of the several factors which control the quality of the braze. The operator should always know what material he is working with and some of its characteristics. Most of the commercial metals are readily brazed. All of the commercial materials were considered. Those which we believed most widely used were selected: stainless steel, copper, silicon bronze, yellow brass and steel. These five were representative of the conditions which would

E. F. Davis is Supervisor, Metals Joining Laboratory, Westinghouse Electric Corp., East Pittsburgh, Pa.

Presented at the Thirty-Third National Fall Meeting, AWS, Philadelphia, Pa., week of Oct. 20, 1952. Closing date for discussion July 15, 1953.

be encountered in production. They were brazed using different combinations of the basic joints, with several silver brazing alloys.

Stainless steel was used as an example of a metal having low heat conductivity. It is easily overheated. The coefficient of expansion of stainless steel is high, and restriction against linear expansion of certain types of joints may cause buckling; thereby increasing the joint clearance beyond that which can be tolerated in good brazing practice. The material is subject to carbide precipitation if the unstabilized grades are brazed. The temperature range of 800 to 1500° F, which is the sensitizing range for unstabilized grades of stainless steel, falls directly in the brazing range. This condition should be explained to the operator or supervisor in detail. Another factor to be considered is penetration of the silver brazing alloy into the grain boundaries. Under certain conditions, if the material is stressed in the area to be brazed or was cold worked prior to brazing, cracking will result.

Stainless steels and other high chrome bearing alloys form refractory oxides when the temperatures are raised to the range used for brazing. This oxide forms a natural barrier against corrosion and, when polished, offers a fine appearance, but this oxide is detrimental to brazing unless the proper precautions are taken for its removal.

Copper is a material which is readily brazed. It has very good heat conductivity which makes it easy to heat uniformly. Flux is required if silver brazing is used but no flux is necessary when phosphorous-bearing alloys are used. Its oxides are not difficult to dissolve. The characteristics are almost opposite those of stainless steel.

Additions of other elements to copper completely change the material characteristics where brazing is concerned. The heat conductivity is reduced, the oxides are less soluble and since the melting temperature is lowered, there is a probability of local melting. Silicon bronze has a unique form of oxide. This material requires care in heating since its oxides form at temperatures as low as 400° F and although they are soluble, their characteristics are different from those of copper and brass.

Mild steel is another material which requires care. It has a low rate of heat conductivity which leads to overheating. The oxides, which form at the red temperatures, are difficult to dissolve. In severe cases flux will not remove these iron oxides.

CLEANING

Precleaning of surfaces is an essential operation if a satisfactory braze is to be made. Oxides should be removed along with grease, dirt, paint or other contaminating materials. Grease, oil and paint form a carbonaceous deposit at high temperatures which inhibits the wetting of the brazing alloys. Dirt and oxide also tend to contaminate the flux, causing it to become unstable. The adequacy of cleaning is usually self-evident from the results achieved. Cleaning can be done by several methods, depending on the material.

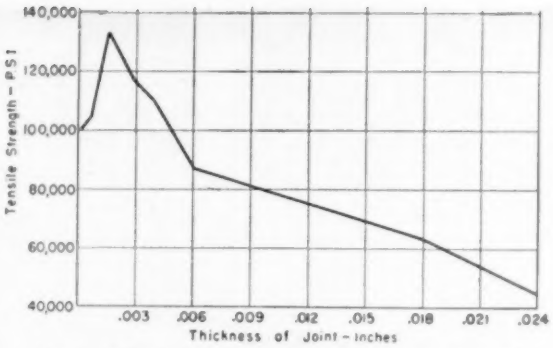

Fig. 1 Effect of joint thickness on tensile strength

Degreasing in trichlorethylene, CCl_4 or some other suitable solvent should precede all other cleaning.

1. (*A*) Stainless steel can be chemically cleaned, abraded or wire brushed.

2. (*A*) Copper and some copper alloys can be bright dipped in a solution of HNO_3-H_2SO_4 with a running water rinse. (*B*) Copper can be wire brushed or abraded with abrasive cloth.

3. (*A*) Mild steel can be wire brushed, abraded or gritblasted.

Cleaning is a must and brazing should not be attempted if the parts have not been properly prepared.

CAPILLARITY

Capillarity is the fundamental phenomena upon which all brazing depends. It is the ability of the molten alloy to draw itself through the forces of surface tension into capillaries formed when parts are joined with small clearances between them. The parts must be designed, formed or machined and fit properly to enable this action to take place. Joint clearances are specified for the different brazing materials and must be adhered to.

It is possible, if clearances and conditions are right, to draw the brazing alloy through a joint as long as 2 in. The temperature must be correct for the alloy being used. The parts must be uniformly heated without localized overheating, the temperature must not exceed the active temperature of the flux. With all the correct conditions it is impossible to draw the alloy through even longer joints.

DESIGN

The design of the parts is a very important part of brazing. The engineer should recognize this and every effort should be made to adhere to sound designs for brazing. The operator should also recognize this fact. If he is taught the effect of poor fit-up on physical properties, he will not knowingly be careless in setting up

his work or attempt to braze poorly fitted work which other workmen have assembled. Unless this is brought to an operator's attention by instruction and physical demonstration he may not be aware of the results. Handy and Harman's curve of joint thickness vs. strength was used to illustrate joint relations. (Fig. 1.)

Three basic joint designs are used in many combinations for all brazed assemblies:

1. Butt.
   (*A*) Butt lap.
2. Tee.
   (*A*) Modified tee.
3. Lap

These are shown in Fig. 2.

The operator is not concerned with the actual designing of the parts, but he should understand through explanation and example why certain sound principles are used in design. For example, if a lap joint is made both parts scarfed for an angular fit, the taper on the parts may be from $^1/_2$T on the ends to full T, 2 in. from the end. The operator should be trained to know the results of improper relationships between the parts and since this joint is a difficult one to shape and fit properly, it was considered to be a good example.

A number of other examples showing the use of tee joints and lap joints were used. Sleeve joints (streamline pipe and fittings) which are examples of the butt-lap type were made with preplaced alloy showing the advantage of preplaced alloy over that fed in from a rod.

BRAZING ALLOYS

There are many types of brazing alloys, some of which are designed for general application, some for specific applications. In this work only five were used: 1 Easy Flo 45—BAg_1; 2 Easy Flo 3 BAg_2; 3 50% Silver BAg_5; 4 Phos Cu. BCuP; 5 Sil Phos $BCuP_3$. The code symbols used are in accordance with those published by the AWS Committee on Specifications for Brazing Alloys.

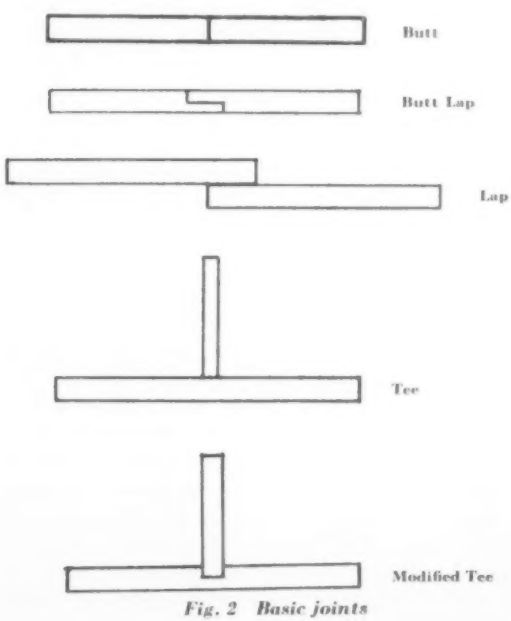

Fig. 2 Basic joints

The characteristics of all five alloys were studied and compared, using Handy & Harman's method of placing a sample of each alloy on a piece of fluxed copper and heating with an oxy-acetylene torch very carefully from the bottom side to melt the alloys by conduction. The melting points were compared and the semimolten range or lack of such a range was observed, Fig. 3.

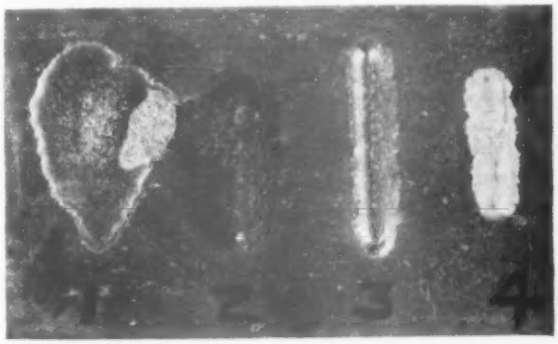

Fig. 3
1, Easy flow. *2*, Sil Phos. *3*, Phos Copper. *4*, ETN.

This was very interesting, some of the men who had been brazing for many years had never before made this comparison.

The first alloy BAg_1 has a very sharp melting point between 1125 and 1145° F, indicating the need for close tolerances in joint clearance, 0.0015 to 0.005 in. maximum.

The second, BAg_2 has a semimolten range of 75° F; from 1195 to 1270° F. This is definitely a fillet-forming alloy. Joint tolerances can be loosened but certain limits must be adhered to.

The fourth and fifth alloys, $BCuP_2$ and $BCuP_3$ each have a semimolten range of approximately 100° F. But alloys with such high percentages of phosphorus would necessarily be brittle and large fillets or other sizable deposits should be discouraged. The alloys should be used sparingly in any particular joint. The thinner the joint the higher the physical properties.

Stresses due to shrinkage on cooling may introduce microcracks which could and do propagate into the base metal.

Alloys are selected for applications because their particular characteristics and properties make them suitable. Some of the requirements are: (1) melting temperature; (2) melting characteristics; (3) corrosion resistance and (4) physical properties.

If an alloy is specified by the design engineer, every effort must be made to comply with the specification. No substitution should be made without the proper authorization.

Certain corrosive environments embodying selective

corrosion of certain elements was given as another reason against substitution by unauthorized persons. The use of alloys which have in the analysis those elements which would be affected by the particular corrosive environment must be limited.

There are many theories regarding the manner in which the bond is formed between the base metal and the alloy. The basic requirements of brazing is the ability of the alloy to bond metals together in the absence of oxides without melting the base metal. Some explanation for this phenomena must be given.

It is known, from metallographic study of brazed samples, that the depth of penetration is in the order of 1 to 1 1/2 grains or 0.0005 to 0.0015 in. in depth.

The equilibrium diagram for lead-tin solder was used to illustrate the principle of alloying two metals of different melting points. In the proper proportions these result in an alloy having a melting point much lower than either of the pure metals. Lead melts at 630° F. Tin melts at 452° F. The resultant eutectic alloy, solder, melts at 352° F.

The eutectic alloy for Cu-Ag is 72% Cu, 28% Ag, the resultant eutectic melts at 1435° F. Copper melts at 1982° F and silver melts at 1761° F.

From the above examples it can be seen that the alloying of two metals, which are to some degree soluble in each other, results in an alloy of lower melting temperature than either component. The same results can be expected, although in a more complex manner, when brazing alloys with an affinity for most of the elements in the base metal are brought into contact with the base metal under the proper conditions and at the proper temperatures.

The need of proper flux for those alloys requiring flux was stressed. All of the alloys having silver in large percentages require some type of flux. The last two alloys mentioned, $BCuP_2$ and $BCuP_3$, both have P as a fluxing agent. Phosphorus has a greater affinity for oxygen than has copper. The action of the phosphorus is to absorb oxygen from the copper oxide and reduce it to pure copper to which the phosphorous alloy will wet. The one alloy contains 5% P, 15% Ag and the balance Cu. The P being limited in its capacity to absorb oxygen by its oxygen solubility, the alloy can be made unstable by overheating the copper or heating for too long a period of time. The work should be heated uniformly to the proper temperature as quickly as possible. If the alloy, either in ring form or in sheet, can be preplaced, melting will automatically occur, but if the alloy must be fed in rod form by the operator, it must be done at the proper temperature.

FLUX

The importance of brazing flux cannot be overemphasized.

There are three main points to be considered in the selection of a flux:

1. Type.
2. Melting characteristics.
   (*a*) Active range.
3. Residue.
   (*a*) Corrosive or neutral.
   (*b*) Removal.

There are many types of flux. Each is designed to do a particular job. The active ingredients, borax, boric acid, fluoride and alkali salts or combinations of these combine with certain other elements to form soluble compounds. For example, borax will combine with and dissolve copper oxide, zinc oxide, iron oxide and oxides of tin, nickel and silver. Boric acid is added to borax for better coverage at lower temperatures; it is fully fluid at 1300° F and dissolves the same oxides as borax.

The borate-fluoride and borate-fluoride-alkali-salts type fluxes combine with the more complex oxides such as chrome oxide, beryllium oxide, tungsten oxide and the oxides formed on aluminum bronze. When the oxides and flux combine, the resulting compounds are either dissolved or they are floated out of the melt due to their low density. Although the flux is designed to combine with these impurities, their solubility is limited, and when the flux becomes saturated, it is no longer a flux but an unstable compound not suitable for brazing. The flux will remain active for a limited time at temperature if the part is not overheated. If overheating occurs, the active life of the flux will be decreased progressively.

The melting range of the flux will determine the type of alloy for which it is suited. The flux must melt before the alloy and remain molten and active throughout the melting range of the brazing alloy. If the flux has a higher melting temperature than the brazing alloy, there is a possibility that flux will be trapped in the joint. If the flux solidifies before the alloy as in a lap joint, capillarity cannot function and the joint will be limited to fillet around the outer periphery which seriously affects the strength of the joint.

Borax and borax-boric acid flux are fully fluid at 1400° F and are known to be active to 1800° F. At the highest temperatures, heating time would necessarily be reduced.

Fluoride and fluoride-alkali types of flux are designed to be fully melted and active at temperatures of approximately 1100° F. These are active through 1600° F.

During the demonstration of a copper plate 2 x 4 x 1/8-in. was used to study flux activity and melting characteristics. The copper was used first without removing any dirt or oxide. The flux did not wet out properly as on clean parts but appeared to ball up and segregate. This is a good indication of oil or grease being present on the surface and can be used by the operator as an indicator of cleanliness. For the next stage the copper was cleaned by degreasing and wire brushing. After the flux was applied all over the surface, the part was heated from the under side. At 600° F the water of crystallization was all driven off and

at 900° the sticky mass wet all over the part, giving protection before the red temperature was reached. At 1100° F the flux was fully active and transparent in color, proving that the flux can be used as an effective temperature indicator. One corner of the copper was overheated and that part became black with a smudged appearance indicating the flux was inactive and the copper had oxidized. The copper was then quenched and the clean area showed no indication whatever of having been heated.

Removal of flux residue is a production problem that is both costly and time consuming. The borax-boric acid type flux is not corrosive, although it is hygroscopic and can be objectionable. If some moisture is picked up following brazing but before painting, it will cause the paint to chip off at that point. The fluoride type fluxes are very corrosive. The flux residue may appear to be dry and dormant, but when moisture is picked up there is a disassociation of the water and the H_2 combines with the fluoride forming HF which is very corrosive. Glass insulation is attacked seriously if adjacent to this residue.

Borax is not water soluble for all general purposes and must be removed mechanically. The residue resembles glass and can be chipped off rather easily.

The low-temperature fluxes are water soluble. Hot water and wire brushing is effective or steam is a good means for removing the flux residue.

If the parts are so designed that flux residue removal is difficult or impossible, the use of a noncorrosive flux should be considered, although the flux should not be changed without first reviewing the brazing alloy characteristics and determining what effect a change in flux may have.

When it is necessary to heat parts over a longer than normal period of time, such as when inner parts not in direct contact with the flame are heated by conduction, a flux designed for longer heating can be used. Such fluxes are available commercially.

INSTRUCTION

Each student was required to braze a number of samples of the different basic joints, using the five materials mentioned previously; stainless steel, copper, silicon bronze, yellow brass and steel. The material was all $^1/_{16}$ in. thick and was cut in pieces 2 in. long and 1 in. wide. These thin sections were used to promote care in heating so that overheating would be avoided. The oxy-acetylene torch was used as a heating medium.

The students were all trained in the safe handling practices for this type of equipment, which included:

1. The proper way to prepare equipment after it has been idle for some time.
   (*a*) Proper sequence of opening tank valves, adjusting pressure, purging each hose separately.
   (*b*) Lighting the torch, adjusting acetylene so that maximum volume of tip is not exceeded and final adjustment of mixture for the type of flame required.
2. The proper shutting down of equipment at end of shift.
   (*a*) Tank valves should be turned off first, each hose bled individually and final release of pressure on regulator diaphragms by releasing hand screw.
3. The student was also taught to recognize by appearance and some of the uses of the three types of flame:
   (*a*) Reducing—Excess acetylene.
   (*b*) Neutral—Balanced ratio of gas.
   (*c*) Oxidizing—Excess oxygen.

The reducing type of flame is used to braze or heat materials such as stainless steel or other materials known to oxidize readily. The flame should be only slightly reducing, indicating the lack of oxygen. If a slight excess of oxygen was present in the flame, the problem of oxidation would be increased.

The reducing flame should not be used on copper unless the copper is known to be oxygen free. On oxygen containing electrolytic or tough pitch copper, the use of a reducing flame, because of the free hydrogen present, causes hydrogen embrittlement and probably serious cracking.

A demonstration was given of the cleaning effect of a reducing flame on a piece of copper which was previously oxidized. A slightly reducing flame held close to the copper readily reduced the oxides. Since hydrogen solubility in copper is increased by increased temperature, the effect of hydrogen on the oxides at the grain boundaries is of the same order as the effect demonstrated on the outer surface.

The neutral flame is used most generally—for most materials.

The oxidizing flame is used to indicate with some assurance that no excess of acetylene is present in the flame. It is used for brazing copper.

Some resistance brazing instruction was given after the basic instruction on torch brazing was completed. This consisted of the proper use of resistance brazing equipment including the proper preparation of the carbon electrodes. It was shown that the heat can be balanced from one electrode to the other by reducing the carbon thickness or by reducing the surface contact area, which increases the current density, or both.

The carbon electrodes can only be used against material with high thermal conductivity, otherwise surface burning of the part will occur. If other than high conducting materials are being brazed—such as steel to copper—the electrode used against the steel must have high conductivity so that the heating will be accomplished by conduction through the copper.

SUMMARY

The results of the use of this course in the training of more than 100 people, including operators, supervisors

and inspectors, was very gratifying. It proved the necessity for training such people in the recognition of the proper conditions required for good quality brazing and in the reasons for using specified materials. The training material consisted of more than the mechanics of operating brazing equipment.* This was essential to the success of the project since properly trained personnel are less apt to use nonspecified equipment, materials or tolerances.

The operators have more respect for inspectors and supervisors when there is evidence of good training.

The people who took the course had some previous experience and, based on this knowledge, it was thought 12 hr would be sufficient time for intensive additional training. This was divided into two 1-hr lecture sessions and five 2-hr sessions in demonstration and practice. This arrangement was very satisfactory.

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(*Continued on page 312*)

The Inert-Gas-Shielded Metal-Arc Welding Process

An Educational Lecture Series presented at the Annual Meeting of the American Welding Society on the Fundamentals of the Inert-Gas-Shielded Metal-Arc Welding Process

Part I

by W. H. Wooding

INTRODUCTION

THE inert-gas-shielded metal-arc welding process is the most recent development for the fusion welding of metals. This process was introduced to industry during the fall of 1948. However, the use of gaseous shields for the protection of metal arc welds from the ravages of the atmosphere is not a new concept in the field of welding.

At the turn of the century, metal arc welding was bidding for industrial recognition. Using bare wire for electrodes, it was a most difficult process of great uncertainty. Lacking the benefit of flux or other shielding media, the weld metal was porous and quite brittle. Industry regarded the process as a "curiosity"; and, as a result, metal-arc welding was restricted for use in minor repair work. It was not until the First World War that the potential value of metal-arc welding was established. At that time, it was realized that the metal-arc welding process required protection from the atmosphere if the quality of the weld deposits was to be improved.

One immediate solution to this problem was then considered to be in the use of special gas atmospheres for protecting metal arc welds. During 1919, it was reported that nitrogen, a gas then considered inert, was not satisfactory for the shielding of metal arc welds. After investigating many other gases, it was discovered in 1926 that satisfactory weld metal could be deposited in an atmosphere of helium. Shortly afterward, argon was also found to be satisfactory, and in 1930, a patent was issued covering the electric arc welding of metals without flux in atmospheres of argon and helium. However, because of the difficulties involved in the shielding of the metal arc and the high cost of the rare gases required, the deposition of metal arc welds in atmospheres other than air was not considered practical. Besides, flux-covered electrodes, capable of depositing good quality weld metal, had become available during the late twenties. These electrodes developed their own atmospheres and could be used in air without special gas shields.

The exigencies preparatory to the Second World War were perhaps largely responsible for reviving interest in a gas-shielded metal-arc welding process. During that time, the aircraft industry was interested in using the electric arc for the fusion welding of magnesium alloys. Northrup Aircraft, Inc., visualized the possibilities of safely using an inert-gas-shielded arc for this purpose and after further development of the almost forgotten process, introduced in 1940 a helium-shielded arc-welding process suitable for the welding of magnesium and its alloys. Later development expanded the use of the process to the welding of practically all gas-free metals except zinc and its alloys. In many applications the process was given preference over the flux-covered electrode. For, not only was it economical to use, due to the improved availability of the gases, but the freedom from slag made the inert-gas-shielded arc-welding process most attractive, particularly for light gage work. Worthy of special note was the rapidity in which the use of the process was expanded in the fusion welding of aluminum and its alloys. In this field with its abundance of material, methods of welding left much to be desired until the advent of the inert-gas-shielded arc-welding process. The success of the process as applied to the welding of aluminum was greatly responsible for the rapid growth of the inert-gas-shielded arc-welding process throughout the metal industry.

This process, in which the electrode is of the non-consuming type, is now referred to as the "inert-gas-shielded tungsten-arc welding process." In this proc-

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ess, an arc is maintained between a tungsten electrode and the work. The arc, the terminal end of the electrode and the molten weld pool are completely surrounded by an inert-gas envelope of either argon or helium. Since the weld metal is not deposited by the tungsten electrode, filler metal when required, must be provided from an external source. It soon became evident to the users of this process that if the electrode was of the consuming type it would be much simpler to provide the necessary filler metal to the weld deposit. Utilizing the basic features of the inert-gas-shielded tungsten arc a second process was developed in which the electrode was fed into the arc and deposited on the work as filler metal. The similarity of both processes is that in each, the arc, the terminal end of the electrode and the molten weld pool are completely enveloped in an inert-gas shield of either argon or helium. However, in the latter process, the electrode, consisting of bare wire, is automatically fed into the arc and deposited on the work as weld metal. Because of this feature, this method is referred to as the "inert-gas-shielded metal-arc welding process," a process which 25 years ago was considered impractical for industrial application.

This discussion will be concerned with the inert-gas-shielded metal-arc welding process, its operating characteristics and the various applications for which it has been used successfully. Since the initial application of the process was for the welding of aluminum and aluminum alloys, most of the early development of the process was concerned with this problem. Consequently, most of the comments on the operating characteristics of the process will be based on observations made during the welding of aluminum.

DEVELOPMENT OF THE PROCESS

At this time, it is proposed to review briefly the advancement of electric arc welding which led to the development of the inert-gas-shielded metal-arc welding process. It was during the 1860's that DeBernardos, a Russian, demonstrated the use of the electric arc for fusing metals together. This method, schematically portrayed in Fig. 1, consisted of establishing an electric arc between a carbon electrode and the work. One wire from a source of electric power was connected to the work and the other wire to a carbon electrode held in an insulated handle. The end of the carbon electrode was touched against the work and then slightly withdrawn to establish the arc. This arc provided a concentrated source of intense heat which quickly melted the abutting edges of the parts being joined. Being a concentrated source of heat, only that portion of the work under the arc was melted and as the arc was moved along the work to melt new areas, those areas previously melted solidified, joining the parts together. In a sense, it is a semicasting process in which the edges of the parts to be joined are reduced to a fluid mass, forming a common puddle. When the molten metal solidifies, the parts are joined or cast together as a continuous member without the need of external pressure. As indicated in the sketch, when it is necessary to add metal to the weld, it must be supplied from an external source.

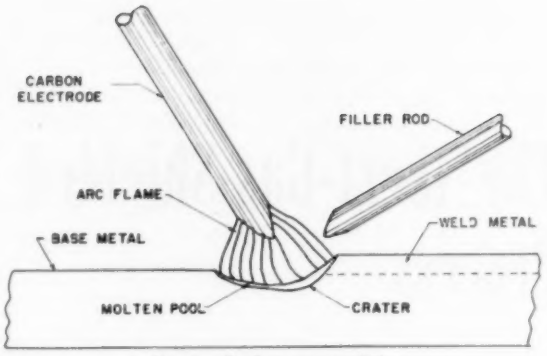
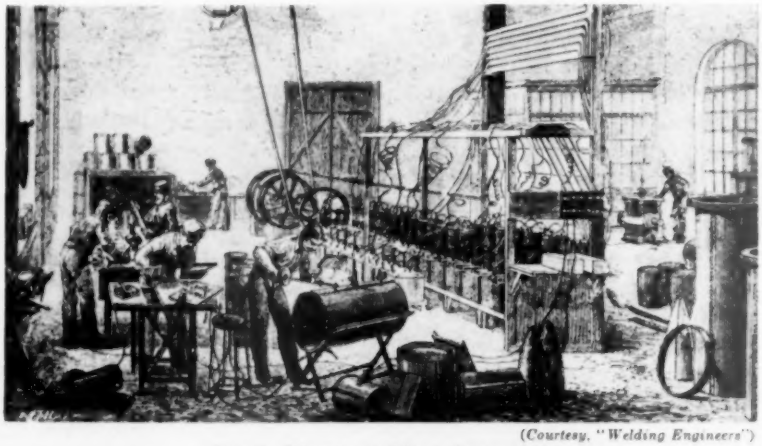


Fig. 1 Carbon-arc welding

Figure 2 is a reproduction of a wood cut showing an electric arc-welding shop around 1887. The several operators shown are in the process of welding various items using the carbon arc. Worthy of note are the long insulated handles used for holding the carbons and the welding sight glasses held by the operators in their free hands. Of particular interest is the source of electric power which was used for welding in those days. As illustrated, this consisted of a bank of electric storage or wet cell batteries and a charging machine for recharging those batteries when they were low in current. Welding at that time was accomplished using direct current, the work being connected to the positive terminal and the electrode to the negative terminal. Today, this electrical connection is com-



(Courtesy, "Welding Engineers")

Fig. 2 Electric welding shop—1888

monly referred to as "straight polarity." With straight polarity, the hotter terminal is located on the work. This condition is most desirable in carbon-arc welding in that the maximum heat is located at the work and not at the electrode. The carbon-arc process, which marks the beginning of all electric arc welding, is still used today with many refinements, but it is not proposed to discuss them at this time.

Shortly after the introduction of the carbon-arc welding process, Slavianoff suggested the substitution of a metal electrode in place of the carbon electrode. He has found that in striking an arc with a metal electrode, the terminal end of the electrode gradually melted away and dropped into the molten pool on the work, adding filler metal to the weld. Thus was born the metal-arc welding process which today is the most popular of all welding processes and is used for the major portion of all fusion welding. A schematic sketch of this process is shown in Fig. 3. As in the carbon-arc process, one wire from a source of electric power is connected to the work and the other to the electrode. The end of the electrode is touched against the work and slightly withdrawn to establish the arc which provides the concentrated source of heat that quickly melts the abutting edges of the parts being joined. However, in this process, the end of the electrode is melted away and deposited on the work as filler metal. The flow of metal from the electrode to the work occurs in large globules which grow at the end of the electrode until they make contact with the liquefied pool on the work causing momentary short circuits. During short circuit, the forces of adhesion and surface tension of the molten surface on the work separate the drop from the electrode and, thus, metal is transferred. It is to be noted that the arc stream, the molten droplet and the molten pool in the arc crater are fully exposed to the atmosphere. Consequently, the weld metal has every opportunity to absorb oxygen and nitrogen from the atmosphere. In this process, the arc was very unstable and the speed with which welding could be accomplished was very slow. Besides, the oxides and nitrides absorbed by the weld metal left much to be desired in so far as the physical properties of the joints were concerned. For these reasons bare-wire metal arc welding was not well received by the metal industry.

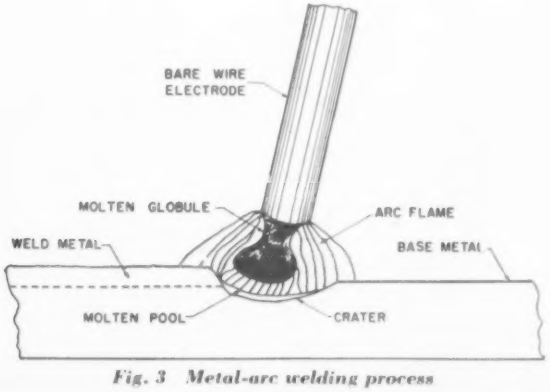


Fig. 3 Metal-arc welding process

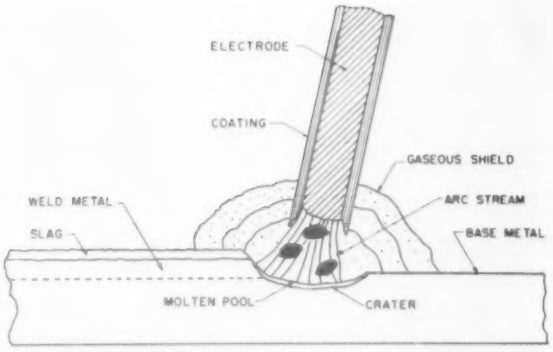


Fig. 4 Shielded metal-arc welding process

Kjellberg of Sweden, in attempting to provide insulated coverings for bare-wire electrode, accidentally discovered the advantages of the covered electrode and his work led to the development of the heavy flux-covered electrodes of today. Figure 4 portrays schematically the action of a flux-covered electrode in depositing weld metal. Here again, the work and the electrode are connected to the opposite terminals of a source of electric power and an arc is established between the work and the electrode. However, the heat of the arc burns away the coating as well as the metal electrode and a gaseous shield is formed which protects the metal in transfer and the molten weld pool. In addition, the covering materials form a slag over the completed weld to protect it from the atmosphere during solidification and cooling. As in the other processes, the arc provides a concentrated source of intense heat which melts the edges of the parts to be joined and, together with the filler metal from the electrode, the parts solidify into one on cooling. There are many advantages of the covered electrode in addition to providing a protective atmosphere and slag coverage of the deposit. The stability of the arc is improved; the fluxing action of the covering scavenges the impurities from the weld metal; and, metal transfer from the electrode to the work is more rapid and occurs in much smaller droplets. Consequently, welding is carried on at much faster rates than could be accomplished with the bare-wire electrode. However, the cleaning of slag is laborious and time consuming.

At the time the flux-covered electrodes were being developed, other investigators were working on the gas shielding of the metal arc. One of the first to report the successful use of helium for the shielding of the metal arc was L. J. Weber. A schematic sketch of his apparatus is shown in Fig. 5. In this apparatus, the bell jar was evacuated over water and filled with the inert gas. The bare-wire electrodes were manipulated by a special insulated holder and the weld deposited on the work as illustrated. Such arrangements would be rather difficult to utilize for the electric arc welding of large structures but the principle here illustrated is the forerunner of the inert-gas arc-welding processes in use today. With this method, the in-

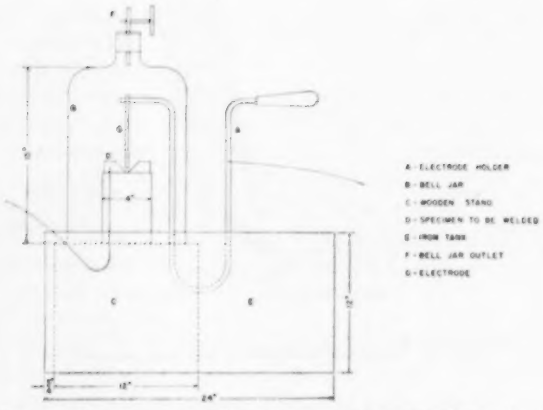


Fig. 5 Metal arc welding in special atmosphere (L. J. Weber, 1926)

stability of the welding arc was comparable to that of the bare-wire electrode in that metal transfer caused short circuiting of the arc.

The final development of this process as it is known today is shown in Fig. 6. This is a schematic sketch of the inert-gas-shielded tungsten-arc welding process showing the arc end of the torch. As indicated, this process is very similar to the carbon-arc process in that the electric arc established between the electrode and the work provides only a concentrated source of intense heat which melts the abutting edges of the parts being joined. When filler metal is required, it must be added from an external source. In this process, inert gas is conducted around the electrode and through a nozzle forming a gas envelope that protects the terminal end of the electrode and the molten weld pool. Since the electrode is not consumed to any appreciable extent, it is held by the welding current conductor in the upper part of the torch. This process has found

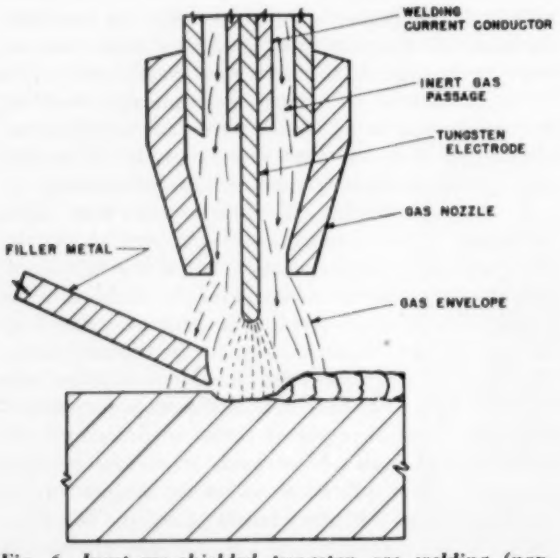


Fig. 6 Inert-gas-shielded tungsten arc welding (non-consuming type electrode)

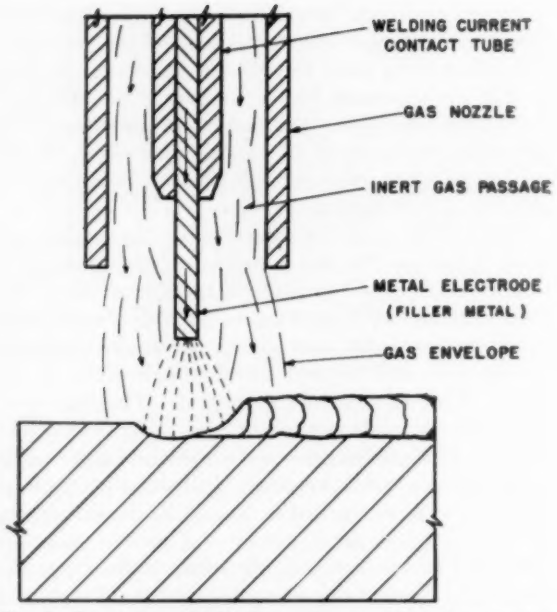


Fig. 7 Insert-gas-shielded metal-arc welding (consuming type electrode)

wide popularity because of its simplicity of operation, its ability to weld practically all metals and the freedom from slag.

The success of this process soon led to the development of an inert-gas-shielded metal-arc welding process in which the electrode was consumed and deposited on the work as filler metal. A schematic sketch of this process is shown in Fig. 7. The similarity of the two processes is quite apparent. In place of the tungsten electrode a metal electrode has been substituted which maintains the arc between its terminal end and the work. However, in this process, the electrode is consumed by the arc and deposited as weld metal. Consequently, the electrode must be fed into the arc at a constant rate to maintain the proper conditions for

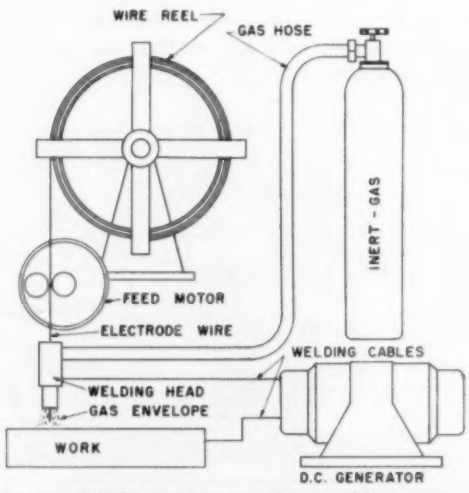


Fig. 8 Simplified inert-gas metal-arc welding equipment

continued welding. Therefore, instead of a connector, the welding current must be conducted to the electrode by a contactor along which the wire must slide. Since in this process, this portion of the equipment not only provides the heat for welding but also the filler wire as well, it is not generally referred to as a torch but rather as the welding head or gun. As in the tungsten arc torch, the outer portion or barrel of the metal arc gun forms the channel through which the inert gas flows to form the gas envelope for the protection of the arc stream and molten weld metal.

For continued deposition of weld metal without interruption of the welding process, it is necessary that the filler metal be fed into the gun from some external source. Figure 8 is a simplified sketch showing the components necessary to obtain these conditions. This illustration shows a reel of electrode wire being drawn by a feed mechanism from the reel and forced into the back end of the gun. Inert gas is supplied to the gun from a container and the welding current is obtained from the usual welding generator. As would be expected, this setup is a bit too simple and requires several controls for practical use.

A rather complete schematic sketch of equipment that has been found practical is shown in Fig. 9. In this sketch it is to be noted that a control unit, welding current contactor, feed motor speed regulator and gas flow regulator valve have been added. This control circuit is quite simple in operation. When the trigger of the gun is depressed, the welding circuit contactor is closed and the inert-gas valve is opened. Thus the electrode wire is energized and the flow of inert gas is purging the system preparatory to developing the necessary gas envelope. When the arc is struck, the control unit energizes the feed motor. As long as the arc is maintained, weld metal is deposited at a predetermined rate set by the adjustable speed regulator of the feed motor. When the trigger is released, the welding circuit contactor opens, interrupting the arc, and the gas flow valve closes stopping the flow of gas. Breaking the arc causes the control unit to stop the feed motor and thus wire is no longer fed into the gun. This gives the operator complete control of the process by merely manipulating the trigger of the gun. It is to be noted that when the welding contactor is closed, the electrode wire throughout its entire length is energized with the welding current; and, therefore, should be protected so that nothing comes in contact with it.

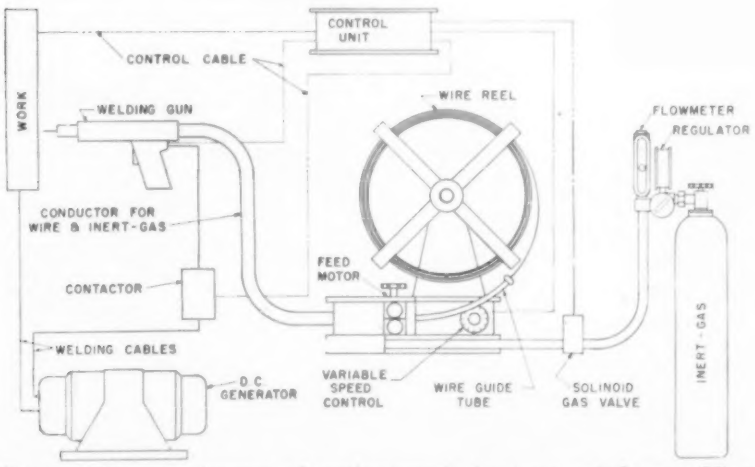


Fig. 9 Schematic diagram of semiautomatic inert-gas metal-arc welding equipment

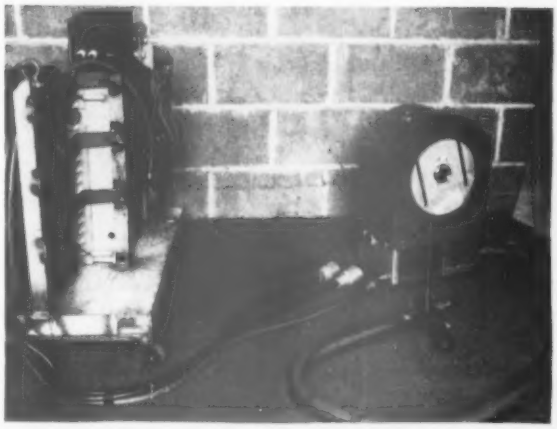


Fig. 10 Inert-gas metal-arc welding equipment

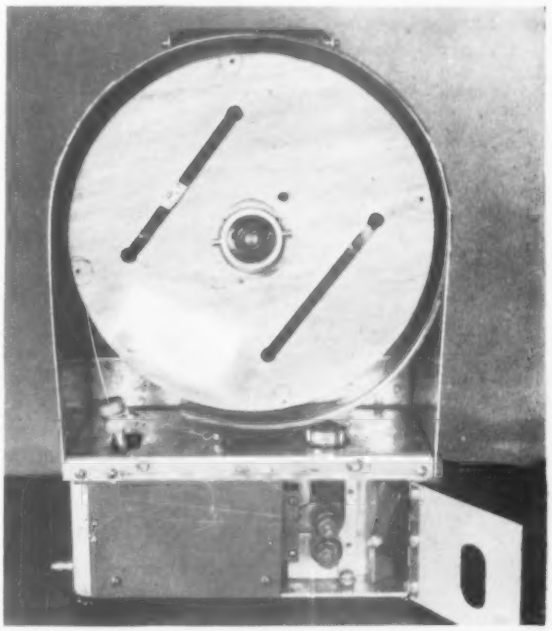


Fig. 11 Wire reel and feed rolls

A photograph of one design of inert-gas-shielded metal-arc welding equipment is shown in Fig. 10. This equipment has been designed for maximum portability

and, as shown, consists of two units. The unit on the left contains the welding current contactor and the control unit. The second unit contains the reel of wire, the feed motor mechanism and the welding gun. The function of these parts is the same as has been described. However, it is to be noted that the reel of wire is completely encased to prevent contact with operating personnel. A close-up of the wire reel and feed motor unit is shown in Fig. 11. This photograph shows the wire reel, the guide tube which guides the wire from the reel into the feeding mechanism and the wire feed rollers. When the wire feed motor is energized, the wire feed rollers turn to pull the wire from the reel and force it through the casing into the gun. Figure 12 is another photograph of this unit showing the feed motor speed regulating control knob. This equipment is a Navy adaptation of the process designed by S. Baum, Shipyard Welding Engineer at the Philadelphia Naval Shipyard.

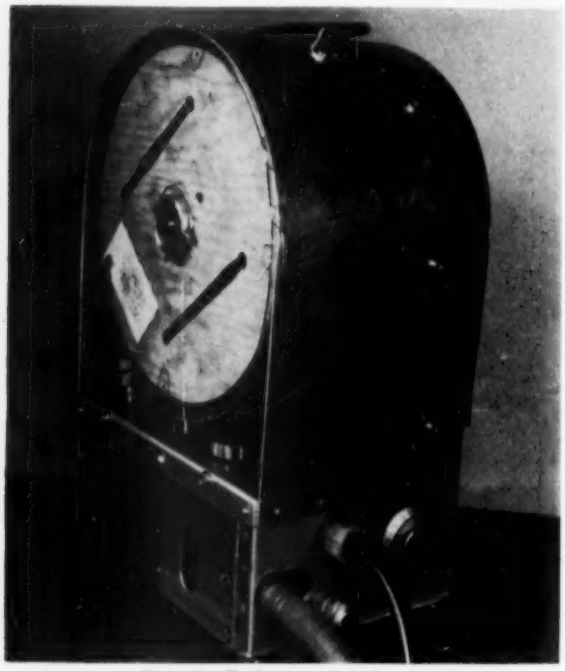


Fig. 12 End view of reel unit

The filler wire conduit is quite an important part of this equipment. As has been previously mentioned the filler wire feed rolls pull the wire from the reel and push it through the conduit into the gun. The length of conduit through which the wire must pass is approximately 8 or 9 ft. Consequently, the wire must be supported throughout that length if it is to be kept from buckling or otherwise becoming jammed in the conduit. Figure 13 is a sketch showing the details of the construction of filler wire conduits. In these conduits the wire is not only guided to the gun but the inert gas also flows through the outer casing to the gun. As you will note, the inner casing is a flexible metal tube which forms a

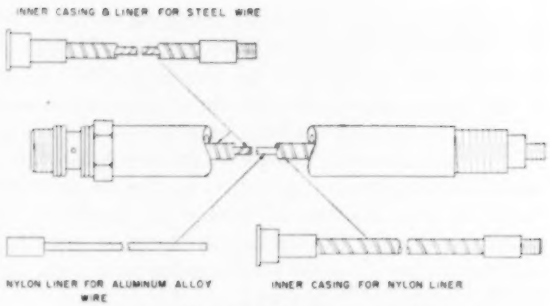


Fig. 13 Sketch of filler wire conduits

guard for the liner. For soft metals like aluminum, the liner is composed of nylon, while for the harder metals such as steel, the liner is also a flexible metal tube. The nylon liner is necessary to keep the aluminum wire from galling during passage. For each diameter wire used in the equipment, a liner having the proper bore must be used since it is the purpose of the liner to support the wire while being pushed from the feed rolls into the gun.

Figure 14 is a photograph showing several conduits partially disassembled. The top one is a conduit properly equipped for aluminum wire. This conduit only guides the wire into the gun and as illustrated, consists of a flexible metal guard tube within which is a nylon liner through which the wire passes. In the lower two conduits, gas as well as wire passes through to the gun. The middle one is equipped for aluminum wire. As shown, this consists of an outer casing of rubber tubing through which the gas flows and an inner casing of flexible metal tubing within which is contained the nylon liner. The lower conduit is equipped for steel wire. It consists of a rubber outer casing through which the gas flows and an inner casing

Fig. 14 Filler wire conduits partly disassembled

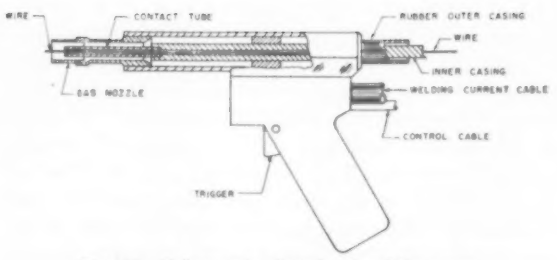


Fig. 15 Schematic sketch of welding gun

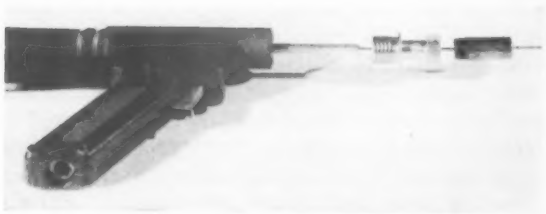


Fig. 16 Welding gun partly disassembled

of flexible metal tubing through which the wire passes.

The welding gun is of a somewhat simple design and, as shown in Fig. 15, consists of the usual barrel attached to a hand grip. The barrel is made up of two components; namely, the guide tube which guides the electrode wire through the gun and the outer casing which surrounds the guide tube forming the gas chamber through which the gas flows. The guide tube connects directly to the inner casing of the flexible wire conduit and guides the wire to the copper contact tube at the nozzle of the gun where it is energized with the welding current. The outer casing of the gun connects directly with the outer casing of the flexible conduit and directs the flow of gas to the muzzle end of the gun. At the muzzle end of the gun, the gas pattern is formed by the gas nozzle and surrounds the electrode wire. This is the gas envelope which protects the arc stream and the molten deposited weld metal. The gun is equipped with a trigger which when depressed energizes the guide tube and copper contact tube through the connecting lug in the back end of the gun. There are other gun designs which incorporate water cooling features for use with welding currents in excess of 250 amp; but, since all operate on the same principle, this gun is used for illustration because of its simplicity. Figure 16 is a photograph showing a gun of this type partially dismantled. The button shown in the grip end is c 'led a jog button. Its purpose is to permit the feeding of wire by operating the feed motor without energizing the welding circuit and gas solenoid valve. Its use is quite important since without it, it would be impossible for the operator to feed wire up into the gun. As you will recall, the automatic circuits of the equipment permit the feeding of the wire only after the arc has been struck. If the electrode wire could not be fed independently into the gun, then there would be no way of striking the arc.

At present, this equipment is produced commercially by two concerns. Figure 17 is a photograph showing a model produced by each company. The one on the left is produced by the Air Reduction Sales Co. and that on the right produced by the Linde Air Products Co. Both of these units incorporate the same operating principles, the major difference being in the manner

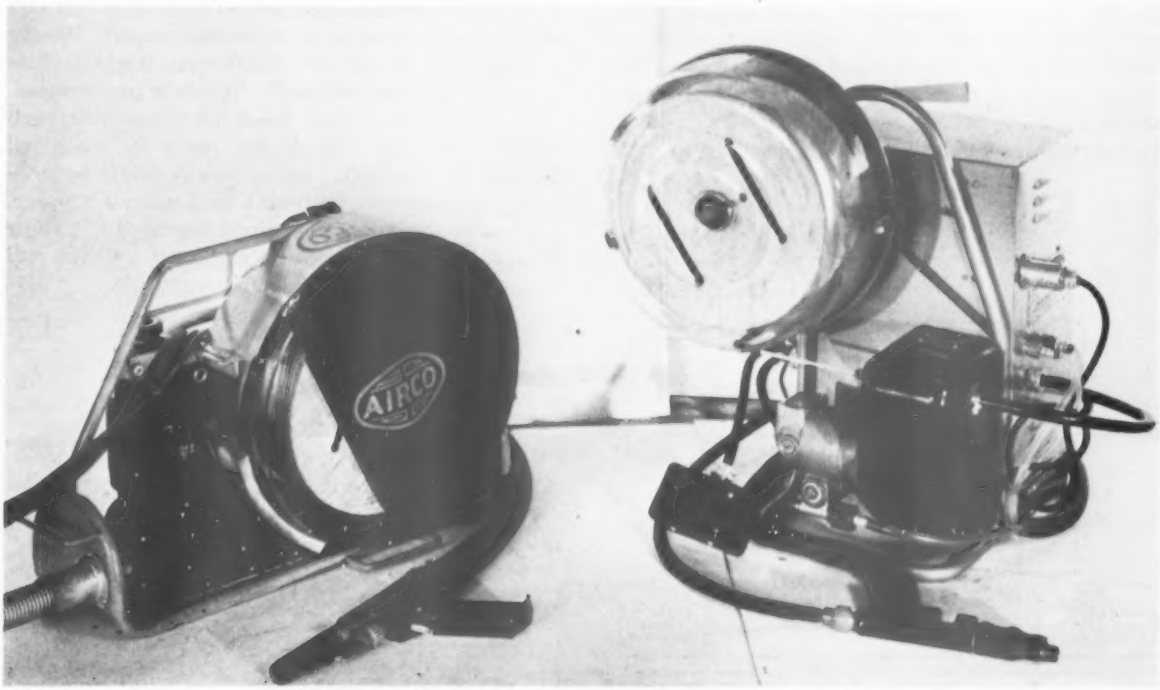


Fig. 17 Commercial inert-gas metal-arc welding equipment

in which the speed of the feed motor is regulated. This equipment is generally referred to as the semiautomatic inert-gas-shielded metal-arc welding equipment; semiautomatic in that though the equipment functions automatically, an operator is still required to manipulate the gun and guide it during welding. There is also automatic inert-gas-shielded metal-arc welding equipment with which welds are deposited without the need of operator manipulation of the welding gun. Such equipment incorporates arc voltage control as a means for governing the speed of electrode wire feed. Consequently, the operator is not concerned with the speed of wire feed when operating the automatic equipment.

OPERATION OF THE EQUIPMENT

This discussion will be primarily concerned with the operation of the semiautomatic inert-gas-shielded metal-arc welding equipment. The equipment is generally used with d-c welding generators or welding rectifiers on reverse polarity; that is, the electrode is connected to the positive terminal. The operation of the equipment is not difficult; and, in the hands of an experienced welder, good quality welds can be deposited with a minimum of instruction. However, it is important that the operating features be fully appreciated before attempting to use the equipment.

As will be recalled, previous reference has been made to the automatic features of the equipment, in which when the arc was struck, the filler wire feed motor was energized so that it fed wire into the arc. So as to better understand this automatic feature, a schematic sketch of the electrical control circuit is presented in Fig. 18. It consists primarily of a high-voltage relay and a low-voltage relay, both of which are actuated by the voltage between the electrode and the work. The high-voltage relay is generally set to operate at about 40 v and the low-voltage relay at about 10 v. When the trigger of the gun is depressed, it closes the welding current contactor which energizes the welding circuit. So long as no effort is made to strike the arc, the voltage between the electrode and the work is the open-circuit voltage of the generator. This should be sufficiently high to energize the high-voltage relay. As long as this relay is energized, the feed motor will run or feed wire into the gun. When the wire electrode is short circuited on the work, the voltage between the electrode and the work approaches zero and both relays are de-energized so that the feed motor is again prevented from feeding wire into the gun. The only time that wire is automatically fed into the gun by the feed motor is when the low-voltage relay is energized and the high-voltage relay de-energized. This condition occurs when the arc is established and the arc voltage is maintained between 10 and 40 v. Any attempt to vary the arc voltage beyond these limits will stop the feed motor. Essentially, this circuit provides off-on control of the feed motor governed by the conditions of the welding arc.

Conditions of the welding arc are influenced by the wire feed. Consequently, it is necessary that the feed be uniform and constant during welding. To insure proper wire feed, the mounting of the wire reel in the equipment and the adjustment of the wire feed rollers are important. As indicated in Fig. 19, the wire is pulled by the wire feed rollers from the spool and pushed into the wire conduit. In mounting the wire reel, the wing nut holding the reel into the spindle should be adjusted so that there is sufficient pressure on the leather washer to brake the reel and prevent backlash when the feed motor stops. Should backlash occur, it would cause the wire to jam at the feed rollers. However, the pressure on the leather washer should not be sufficient to retard the turning of the reel and cause slippage of the wire in the feed rollers. Having adjusted the wire reel, the wire is fed into the feed rollers and the rollers are adjusted to provide positive feed. This is done by turning the roller adjustment knob which compresses a spring that forces the idling roll against the drive roll. This pressure should be sufficient to insure positive feed of wire without slippage, but not so great that the wire is deformed in passing through the rolls. Any deformation of the wire will cause difficulty on being fed into the gun.

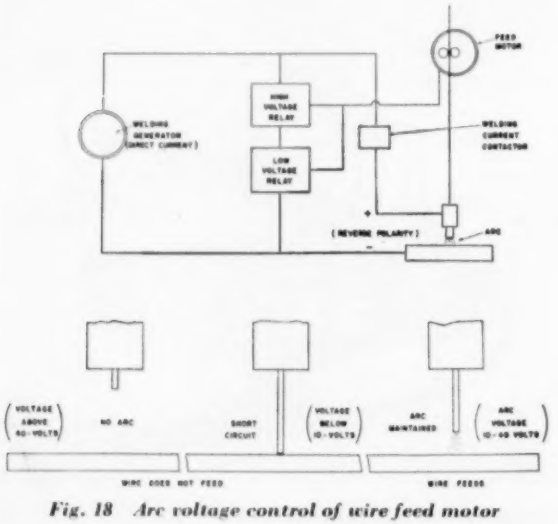


Fig. 18 Arc voltage control of wire feed motor

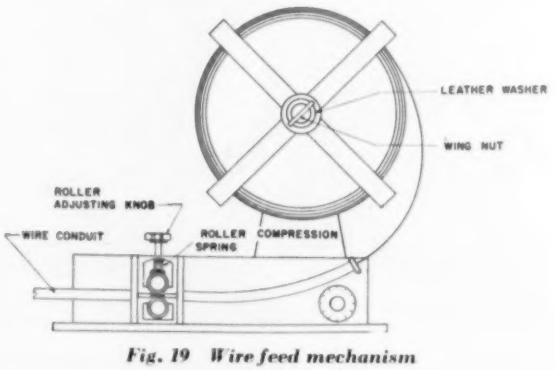


Fig. 19 Wire feed mechanism

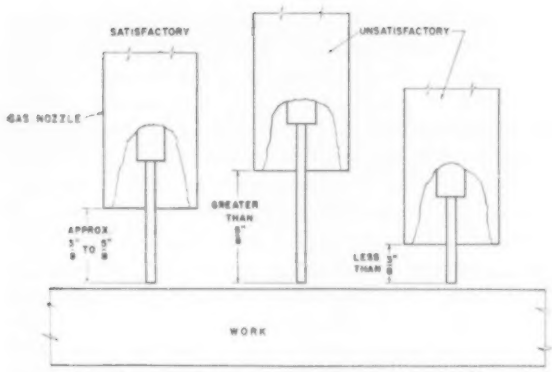


Fig. 20 Proper wire length for striking arc

Having fed the wire into the feed rollers, the jog button on the gun is depressed energizing the feed motor which feeds the wire through the conduit into the gun. It is necessary to feed the wire until a sufficient length extends beyond the gun to facilitate striking the arc. The distance the wire extends beyond the gas nozzle of the gun is quite critical. Figure 20 schematically portrays satisfactory and unsatisfactory wire lengths for striking the arc. When the wire extends from $^3/_8$ to $^5/_8$ in. beyond the gas nozzle, little difficulty will be experienced in striking the arc and obtaining a good weld deposit at the start. However, when the length of wire exceeds $^5/_8$ in. the gas nozzle is too far away from the terminal end of the electrode to provide satisfactory inert gas shielding to protect the weld start. When the length of wire is less than $^3/_8$ in., the arc will burn back to the contact tube before the feed motor can effectively push wire into the gun. This is caused by the infinitesimal time lag of the equipment in providing full speed wire feed on striking the arc. When the arc does burn back to the contact tube, the filler wire generally becomes welded to the tube and it is necessary to disassemble the front end of the gun to free the wire.

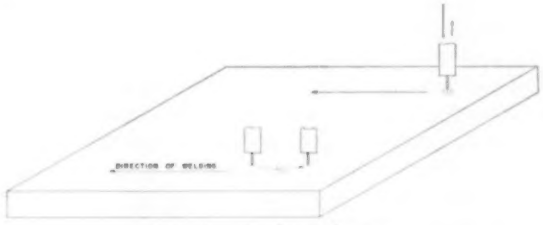


Fig. 21 Striking the arc

The technique of striking the arc does not differ materially from that used in any other metal-arc welding process. As illustrated in Fig. 21, either the scratch or peck method may be used. However, it is preferred that, particularly for beginners, the scratching method be used. Other than the most skillful operators will have difficulty in striking the arc by picking, since the wire generally will become welded to the work before the arc can be established.

The conditions for satisfactory operation of the equipment are given in Fig. 22. These values represent a range of conditions for the deposition of aluminum alloy weld metal in the flat or downhand position. The conditions for argon differ somewhat from those used with helium. This is primarily due to the difference between the two gases with respect to their ionization potential which is somewhat higher for helium (15.68 vs. 24.46).

438 Aluminum Alloy Electrode Wire, $^1/_{16}$ In. Diam.

Inert gas	*Wire feed, in./min.*	*Welding current, amp*	*Arc voltage*	*Gas flow, c f h*
Argon	160–220	180–240	22–25	40–80
Helium	160–220	160–220	28–31	80–150

Fig. 22 Welding conditions, semiautomatic inert-gas-shielded metal arc welding, flat position

The proper adjustment of the equipment for welding differs somewhat from the normal procedure used in metal arc welding. Figure 23 illustrates the steps considered necessary to obtain good operation. First, the wire feed motor control is set at the proper speed to give the required wire feed per minute. The trigger of the welding gun is depressed to open the gas solenoid valve and the flow of inert gas is adjusted by regulating the reducing valve at the tank. A flow meter should be incorporated in the gas system so that proper adjustment is obtained. Remember, if the welding generator is operating, depressing the trigger of the gun will energize the welding circuit and the equipment must be handled with extreme caution. Next, the welding

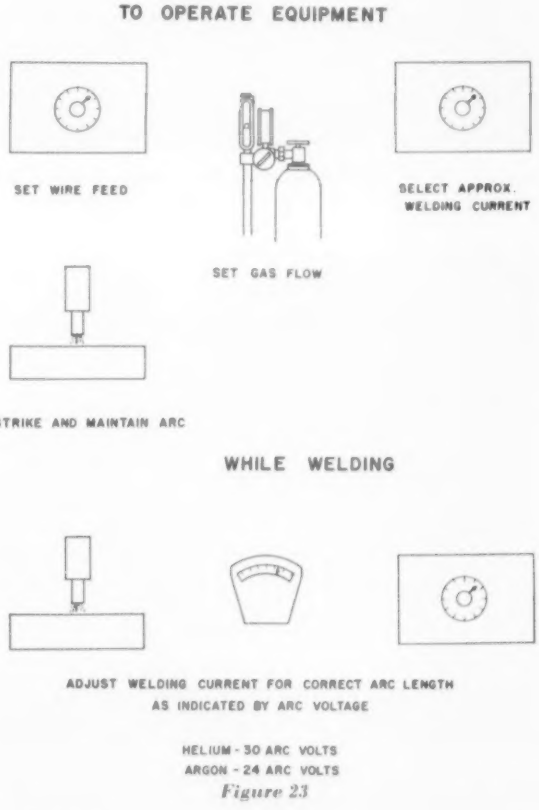

TO OPERATE EQUIPMENT
SET WIRE FEED
SET GAS FLOW
SELECT APPROX. WELDING CURRENT
STRIKE AND MAINTAIN ARC
WHILE WELDING
ADJUST WELDING CURRENT FOR CORRECT ARC LENGTH AS INDICATED BY ARC VOLTAGE
HELIUM - 30 ARC VOLTS
ARGON - 24 ARC VOLTS

Figure 23

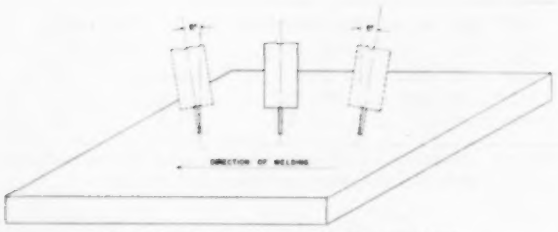


Fig. 24 Angle of gun during welding

Fig. 25 Operator prepared to deposit weld in flat position

Fig. 26 Operator prepared to deposit weld in vertical position

generator is adjusted to the approximate welding current. The equipment is now ready for welding. The trigger of the gun is depressed and the arc is struck on a piece of scrap material for a trial weld. While the arc is maintained, the welding current is adjusted at the welding generator until the proper arc voltage is obtained. For welding aluminum, this is approximately 30 v in a helium atmosphere or 24 v in an argon atmosphere. Arc voltage is a function of three variables; namely, the shielding atmosphere, the welding current and the speed of wire feed. Generally it is much easier to fix the atmosphere and speed of wire feed and obtain the desired arc voltage by adjustment of the welding current. The proper arc voltage can be obtained by regulation of the speed of wire feed but such a procedure is quite tedious and seldom proves entirely satisfactory. However, operators having considerable experience with the equipment, are able to set the proper wire feed and welding current conditions and obtain the desired arc voltage with little or no readjustment.

Either a backhand or a forehand technique may be used for depositing welds provided the angle at which the gun is held to the work is not too great. As illustrated in Fig. 24, this angle may vary within 5° of the normal to the weld. It is extremely important that this angle should not vary more than that indicated otherwise the weld deposit will not be properly shielded by the flow of inert gas from the nozzle of the gun. This is particularly true when welding with a forehand technique. Tilting the gun in other directions should be limited to a maximum of 10°. Tilting at angles greater than 10° will cause severe undercut on the near side of the weld. Consequently, when weaving motions are used to deposit wide layers of weld metal, care should be taken to move the gun in a plane normal to the weld deposit.

Figure 25 is a photograph of an operator in position preparatory to striking the arc and depositing a weld in the flat position. He is ready to establish the arc by the scratching technique and will deposit the weld in a backhand manner. Also note the position of the wire conduit. He has carefully brought it up over his shoulder so that it will not become kinked or bent to a sharp radius which would cause interference with the wire feed. This is extremely important to the satisfactory operation of the equipment. Figure 26 shows another operator in position ready to deposit a vertical weld. Note the position of the wire with relation to the end of the groove. He is prepared to strike the arc by the scratching technique and will deposit the weld in a backhand manner vertically up. Also note how carefully he has laid the wire conduit over his shoulder.

Contact tubes are quite important to the successful operation of the equipment. The nozzle end of the tube should be swaged so that the barrel is choked to provide good contact with the wire. As shown in Fig. 27, when the contact tube is straight and not choked, the lay of the wire causes it to wander around

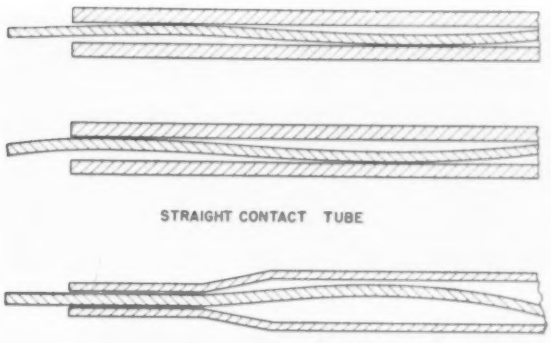


Fig. 27 Sketch showing proper and improper contact tubes

as it is ejected from the tube. Not only does this condition give the operator considerable difficulty in directing the arc but the wire makes more or less point contact with the tube at varying distances from the end causing a continual change in the voltage characteristics of the arc. This is due to the slight change in resistance resulting from the change in length of the wire between the point of contact in the tube and the arc terminal end. With the swaged contact tube, not only is the wire held axially with the tube but the surface of contact is near the end of the tube. It is essential for trouble-free operation that the end of the contact tube be swaged or choked so that the wire makes positive contact near the end of the tube. However, the swaged end should not be sufficiently choked to interfere with the passage of the wire. This is equally important since, as will be remembered, the wire is being pushed up through the conduit by the feed motor and any interference with its passage will cause buckling of the wire in the conduit.

The position of the contact tube with respect to the gas shield nozzle also is important. Figure 28 presents the proper and improper locations of the tube with respect to the gas nozzle. For satisfactory operation, the end of the contact tube should be recessed $^1/_4$ to $^1/_2$ in. within the gas nozzle. Should it exceed this distance, the length of wire extending beyond the contact tube is too long and will melt off at the contact tube causing difficulty in maintaining the arc. When the

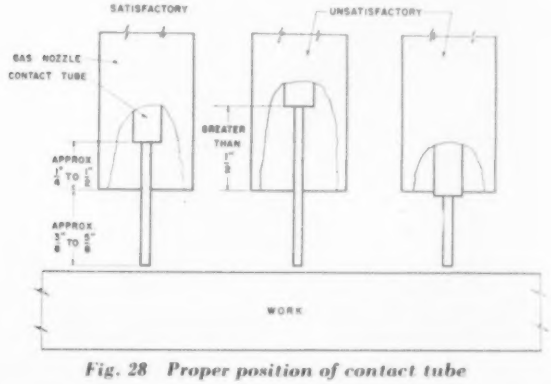


Fig. 28 Proper position of contact tube

contact tube extends beyond the gas nozzle, considerable difficulty is experienced in attempting to maintain an arc with satisfactory gas coverage. If the operator tends to bring the gun too close to the work, the arc will burn back and weld the filler wire to the contact tube. It is also important that the contact tube be concentric with the gas nozzle. This is quite obvious since it is most desirable to have the arc located as near the center of the inert-gas shield as possible.

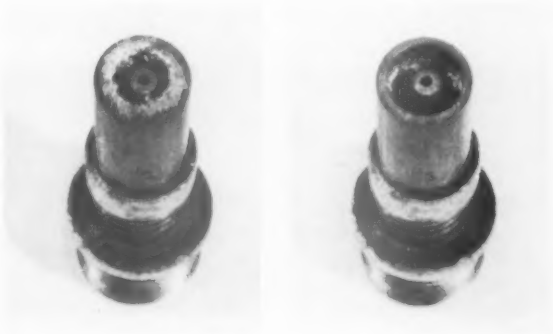


Fig. 29 Weld spatter in gas nozzle

Occasionally, the gas nozzle will become clogged with weld spatter as shown in Fig. 29. This is not abnormal and is to be expected in view of the proximity of the nozzle to the welding arc. However, by slightly tapping the nozzle against the work, this spatter is readily dislodged as shown on the right. Care should be taken that the trigger is released and the welding circuit de-energized when tapping the nozzle against the work to remove spatter.

The condition of the filler wire as it is pulled from the reel and pushed into the conduit is of utmost importance. If a constant uniform wire feed is to be expected, the filler wire must be free of kinks and

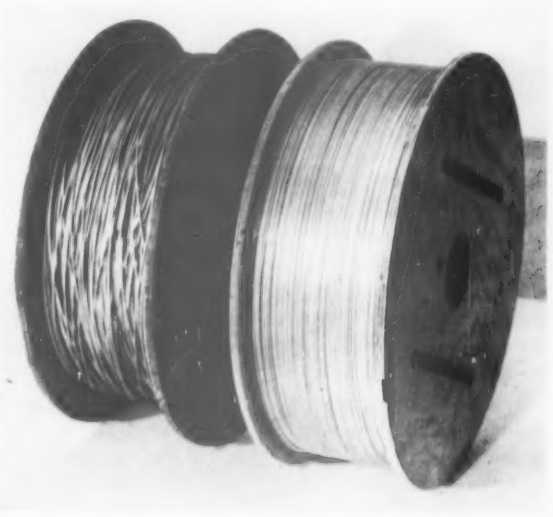
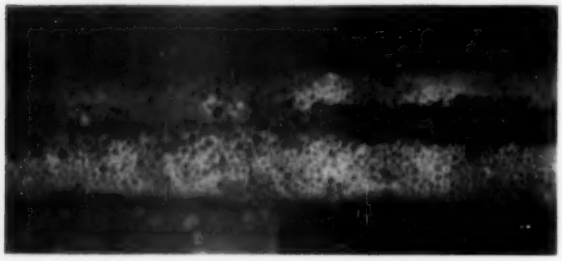
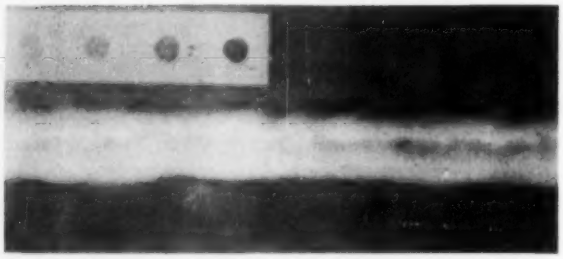


Fig. 30 Proper and improper winding of reels

must unwind from the reel without interference. Figure 30 illustrates good and bad reels of wire. The one on the left has been wound haphazardly on the reel. In unwinding, the individual turns of wire will become snagged and tangle with each other causing a nonuniform wire feed. The reel on the right has been level wound and in unwinding, the turns will come off freely without interference. Since the turns of wire do not cross over each other, the wire will be free of kinks and will pass through the system, particularly the contact tube in the gun, without difficulty.



As-drawn

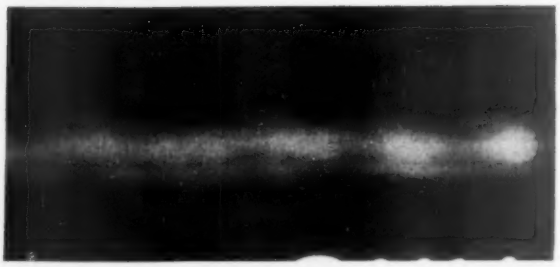


Chemically cleaned (lustric or zincated finish)

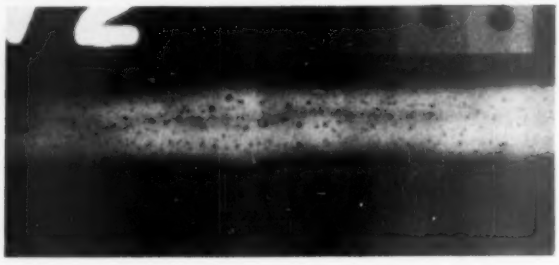
Fig. 31 Effect of wire surface condition on porosity of weld deposit

The surface condition of the wire is also important. After drawing to its final diameter, it must be cleaned of all die lubricants if porosity-free welds are to be obtained. As shown by the X-ographs presented in Fig. 31, if the wire is not cleaned before use, the weld will be quite porous. However, with chemically cleaned wire, the weld is free of porosity. This condition can also be caused by the surface condition of the wire. The surface of aluminum oxidizes very rapidly and this oxide skin readily absorbs moisture from the atmosphere. Wire in this condition produces welds similar to that shown for the "as-drawn" condition. It has been shown by laboratory tests that this oxidized skin may hold as much as 70% of the total hydrogen content of the wire. Removal of the surface hydrogen readily produces welds similar to that shovn for the chemically cleaned wire.

While we are discussing the effect of impurities on weld quality some mention should be given to the effect of the purity of the inert gas. Figure 32 shows X-ographs of two similar welds, one produced with high-purity welding grade helium and the second produced with a nonwelding grade of helium. The difference



High purity helium gas (99.6%)



Commercial purity helium gas (98.5%)

Fig. 32 Effect of gas purity on weld deposits

in purity between these two gases is 99.6 and 98.5%. Any slight contamination of the shielding gas with either water vapor or hydrogen will have an adverse effect on weld quality.

In the welding of aluminum with this process, cleanliness is next to Godliness and, not only must the wire and gas be free of contaminants but the aluminum base plates in the way of the weld also should be cleaned. Prior to welding, the plate material in the way of the weld should be either ground or power wire brushed to remove all surface oxide and other surface contaminants such as paint, grease and dirt. As shown in Fig. 33, the plate which the operator is about to weld has been thoroughly cleaned in the way of the weld. Also of interest in this photograph is the protective clothing the operator is wearing. This consists of leather guantlets, leather apron and leather cape with long sleeves. This clothing is not only flameproof but also gives adequate protection from the radiation of the arc. If leather clothing is not available, wool is a satisfac-

Fig. 33 Cleanliness of plate in way of weld

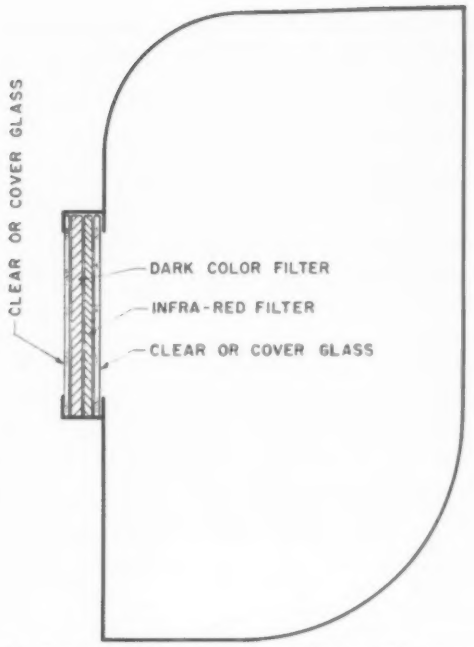
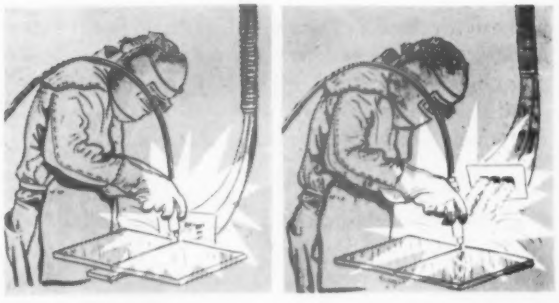


Fig. 34 Protective filter lens system face shield, inert-gas-shielded metal arc welding

tory substitute. Cotton clothing should not be used. Remember, this arc stream is fully exposed and gives off considerable quantities of ultraviolet and infrared radiations. Cotton clothing will not provide a suitable barrier for these radiations and such fibers will deteriorate on continued exposure to the arc. Consequently, without proper clothing the operator may be severely burned from the radiations of the inert-gas-shielded welding arc.

Of equal importance is the protective lens system in the face shield. Figure 34 illustrates a lens system which has been found to provide adequate protection for the operator. This consists of a dark color filter to reduce the brilliancy of the arc, the shade of which should be that recommended for electric arc welding in the range of welding currents used. However, this filter in itself has not been found to be fully effective in providing eye comfort for the operator. When used alone over extended periods of exposure to the arc, operators complain of eye burn. To remedy this, a second filter is used which more completely filters out the infrared rays. This infrared filter is colorless and consists of a glass coated with a very thin metallic film. It does not reduce visibility appreciably. Of course, cover glasses are used to protect the filters from weld spatter and handling.

As in every metallic-arc welding process, ventilation is important. The right and wrong methods for ventilating the inert-gas-shielded metal-arc are presented in Fig. 35. The placing of the exhaust duct in close proximity to the weld arc should be avoided. In this position, the passage of air to the duct is usually of such high velocity that it destroys the inert-gas shield.



WRONG RIGHT

Fig. 35 Method of ventilation

Adequate ventilation can be obtained by placing the duct some 12 or more inches above the arc so that the rising fumes are pulled away from the operator without disturbing the inert-gas shield. During welding, ozone and oxides of nitrogen are produced, either of which if allowed to build up in concentration will become toxic to the operator. Also, the use of 43S aluminum silicon filler metal wire produces fumes of alumina and silica which are irritating to the lungs. However, with proper ventilation as here illustrated, fume concentrations are kept well below the danger limit. Should exhaust systems be not available, other methods such as a ventilated face shield will prove adequate.

Figure 36 is a photograph of an operator ready to deposit a weld. He has already set the welding conditions to provide the proper burn-off rate to establish the correct arc voltage for the inert-gas shield he is using. As will be recalled, to do this, the wire feed was selected and then by trial the current was set to obtain the proper arc voltage. The wire extending from the nozzle of the gun is of proper length so that there will be no difficulty in striking the arc. He has placed the wire conduit carefully over his shoulder to prevent any sharp bends from interfering with the

Fig. 36 Welding under proper conditions

uniform wire feed. The gun is being held at the proper angle to provide adequate gas coverage for the arc and molten weld metal. The plate material has been cleaned in the way of the weld. He is also observing the proper safety precautions by wearing leather safety clothing and face shield.

The exhaust duct is sufficiently elevated to remove the fumes of welding without interfering with the inert-gas shield that will surround his arc.

So far, this discussion has been an attempt to acquaint the reader with the historical background leading to the development of the inert-gas-shielded metal-arc welding process and the operating features of the semiautomatic equipment. It is hoped that some idea has been gained concerning the operation of the equipment, the difficulties that may be encountered during operation and the safety precautions which should be observed.

Editorial Note: The second part of this Lecture Series will be reproduced in the May issue of THE WELDING JOURNAL

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(*Continued from page 298*)

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Anderson Ranch Dam Penstock Test Fracture Repaired by Welding

Design of the penstock and outlet pipe system, welding techniques and the successful repair of a fracture in the pipe shell

by P. J. Bier

THIS article describes the hydrostatic pressure test applied to the steel penstock header of the Anderson Ranch Power Plant, the resulting development of a fracture in the pipe shell, and the subsequent successful welding repairs of the pipe. The article also discusses the design of the penstock and outlet pipe system, the welding techniques employed in their fabrication, and the installation of the pipe system.

Anderson Ranch Dam and Power Plant are major features of the Bureau of Reclamation's Boise Project in Idaho. The dam, highest earthfill dam in the world, was completed in 1949; the 27,000-kw power plant was placed in service in 1951.

DESIGN OF PENSTOCK AND OUTLET PIPE SYSTEM

The penstock and outlet pipe system for Anderson Ranch Dam serves the dual purpose of delivering water to three hydraulic turbines and releasing irrigation water through five outlet pipes. Although the power plant is designed to house three generating units, the initial installation includes only two units. A header system with penstock and outlet branches was found to be the most rational method of fulfilling these requirements.

The 15-ft-diameter header was installed in the 20-ft-diameter concrete-lined diversion tunnel after river diversion through the tunnel was completed. Near the end of the tunnel the header turns left at 90 deg, and forms the penstock manifold which includes the three branch penstocks. After this power take-off, the header continues downstream as a reducer which, with the five 72-in. outlet pipe branches, forms the outlet manifold. The upper end of the header is concreted into the tunnel for a distance of 90 ft which forms an anchor and tunnel plug. Following this anchor the header is freely supported at 32-ft centers by means of ring girders and columns resting on cast-steel base plates, which are set on and anchored to concrete piers. Also encased in concrete are the 90 deg bend and the penstock and outlet manifolds; the ends of the branch penstocks are exposed in the powerhouse.

Design of the pipe system was based on conventional practices followed by the Bureau of Reclamation for the penstocks at Grand Coulee, Shasta, Green Mountain and other dams which were constructed prior to Anderson Ranch Dam. A normal flow of 756 cfs and a total head of 420 ft were used in the computations. This total head includes a static head of 326 ft and a water-hammer head of 94 ft, which may develop under normal operating conditions with closure in 10 secs from part gate under full load. The pipes were fabricated from carbon steel of firebox quality, ASTM Designation: A89 – 43, Grade B (now designated as A285). ASTM specifications for this type of steel and range of thickness call for a maximum carbon content of 0.22% and a maximum manganese content of 0.80%.

For physical properties, the following minimum requirements were specified: a tensile strength of 50,000 psi, a yield point of 27,000 psi, and a percent elongation, in 2 in., of 1,650,000/tensile strength. Plate thicknesses of the pipes were computed by the membrane formula of $t = rplse$, using a design stress (s) of 13,500 psi. A joint efficiency (e) of 90% was used, as all welds in the pipe shell were required to be double butt welded and fully radiographed. Symbols (r) and (p) represent respectively, the radius of the pipe in inches, and the internal pressure in psi.

The computations required plate thicknesses from $1^1/_4$ to $1^3/_8$ in. between supports (with an increase of $^1/_4$ in. over the supports) for the 15-ft header, $^3/_4$ in. for the 90-in. penstocks and $^5/_8$ in. for the 72-in. outlet pipes. Plate thicknesses in the penstock and outlet pipe branches varied from 1 to $1^5/_8$ in.

Expansion joints were used only for the exposed ends of the penstocks. The exposed portion of the

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15-ft header in the tunnel was provided with a make-up section and final closing joint near the downstream end. The make-up section was fitted into the header and the closing joint was welded after contraction of the pipe shell during low temperature. By this means, longitudinal tension in the header was eliminated. The pipe system was provided with a filling line and drain connection, and with a number of manholes for inspection and maintenance.

FABRICATION AND WELDING

Pipe courses for the 15-ft header were fabricated from two plates providing two longitudinal joints, and for the penstock and outlet branch pipes from one plate having one longitudinal joint. Steel plates were furnished jointly by United States Steel Corporation and by the Bethlehem Steel Corporation. Certified mill tests reports showed that the steel conformed to ASTM standard specifications. The pipe courses were made in 8-ft lengths, then welded into 16-ft erection sections. Welding on straight sections was generally performed on automatic machines using the Unionmelt process. Curved joints between bend segments and on branch connections were manually welded.

Since the 15-ft-diameter header sections exceeded rail shipping clearances, they were fabricated in a field fabricating plant near the dam. Penstock and outlet branch pipes, and portions of branch connections not in excess of shipping limitations were fabricated at the contractor's home plant. The pipe system was fabricated under two contracts: the outlet manifold was furnished by the Willamette Iron and Steel Company of Portland, Oregon; the remainder of the system was fabricated by the Southwest Welding and Manufacturing Company of Alhambra, California. The Southwest Welding and Manufacturing Company set up a field fabricating plant for the 15-ft header sections and for the completion of the branch connections. All plates for these large sections were prepared and rolled at the contractor's Alhambra plant, then welded into pipe courses and erection sections at the field fabricating plant.

For manual welding E-6010 electrodes were used. Each weld pass was cleaned and peened before the next pass was deposited. Double-welded butt joints were used for the pipe shell and all such butt welds were radiographed. Unacceptable defects were removed by flame gouging or chipping and were repair welded. Repair welds were reradiographed until sound welds were obtained. Thermal stress relieving was not required, except for the segments of the branch connections incorporating the outlets, which included the heaviest plates and welds.

Because of shipping limitations it was not feasible to stress relieve entire branch connections or the 15-ft header sections unless a stress-relieving furnace would have been installed at the field fabricating plant. The construction of such a large stress-relieving furnace was considered to be impracticable. The 1943 edition of the API-ASME Code, which with a few exceptions was followed as far as it was applicable to pipe required thermal stress relieving for the 15-ft-diameter pipe where the plate to be welded exceeded $1^1/_4$ in. in thickness at the weld. For large parts exceeding rail shipping clearances, which had plate thicknesses in that range, the code permitted the use of mechanical peening in place of thermal stress relieving.

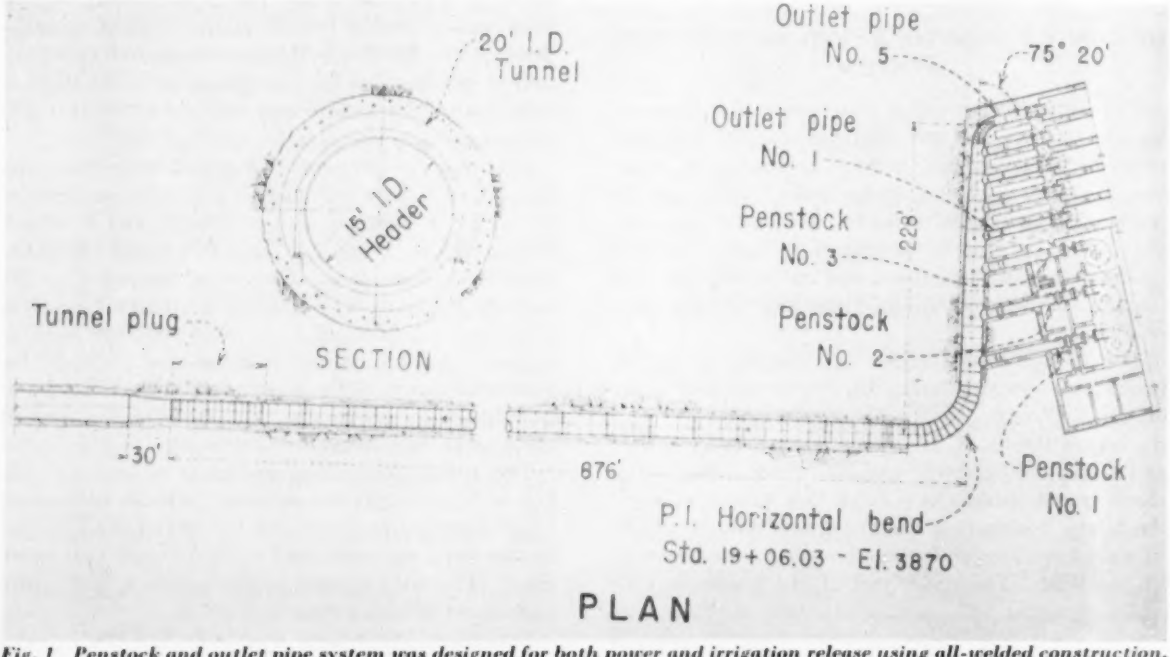


Fig. 1 Penstock and outlet pipe system was designed for both power and irrigation release using all-welded construction, in conformance with the API-ASME Code

Fig. 2 Proof hydrostatic pressure test produced a longitudinal cleavage-type fracture in the pipe shell which presumably was caused by a stress raiser due to an undisclosed defect in a weld

Consequently, peening was used not only on shop joints but also on all field-welded joints. This procedure was considered to be entirely adequate in this case, inasmuch as the safety of the penstock and outlet pipe system was to be determined by proof hydrostatic pressure tests before placing it in service.

Prior to the installation of the 15-ft header in the tunnel downstream from Section 17, four 16-ft pipe sections were assembled into units 64 ft long and welded together. This was done at the tunnel entrance, using heavy structural steel trunnions provided with rollers to rotate the pipe while a girth joint was welded. The four sections were first tack welded into a unit. Welding then proceeded simultaneously on both sides of the pipe, on top outside and on the bottom inside; all welds being deposited downhand. All intermediate weld passes were cleaned and peened to reduce welding stresses. By this method the number of girth joints to be welded in place in the tunnel was reduced to a minimum and better welds were obtained.

INSTALLATION

The first 17 header sections at the upstream end were installed by the general contractors for the dam and power plant. Five of these sections were concreted into the tunnel lining where keyways had been provided for that purpose. The concreted sections formed the tunnel plug and anchor which were back-grouted under pressure against the concrete lining. Installation of the remainder of the pipe sections started with the outlet manifold at the downstream end, then proceeded to the penstock manifold, both of which were encased in concrete after they had successfully passed the specified hydrostatic pressure tests. Installation of the 15-ft header in the tunnel followed.

Access to the tunnel was had from its downstream end before it was closed by the 90 deg bend. This bend and the concrete anchor around it were placed after the header had been installed in the tunnel but before the final closing joint was welded. As a low temperature of 45° F prevailed in the tunnel in December 1949, the closing joint was welded up during that month. The concrete support piers for the header in the tunnel were placed in pockets excavated into the 24-in. tunnel lining. All anchor bolts for the base plates of the supports were set in place prior to the installation of the header. The base plates were grouted after the installation and adjustment of the supports. Two sheets of compressed asbestos packing, graphited on the contact sides, were placed between the machined ends of the support columns and the cast-steel base plates. This was done to facilitate free temperature movement during installation and prior to the welding of the closing joint.

The 64-ft-long assemblies were transported from the tunnel portal into the tunnel by means of a special trolley running on rails. After a pipe assembly was placed in position on temporary timber supports and aligned with the adjoining section upstream, the girth joint was tack welded. All welding in the tunnel was manual; all-position electrodes were used. Welding usually proceeded simultaneously in several locations around the periphery of the pipe. Before welding the tack welds were removed by flame gouging. The joint was first welded from the outside and the root of this weld was back-chipped to clean metal before proceeding with welding on the inside of the pipe. Whenever practicable, welding proceeded symmetrically on both sides of the pipe to minimize the tendency of rotation. All welds in the pipe shell were radiographed and defects were repair welded and reradiographed to check the quality of the repairs.

All welding, both in the shops and in the tunnel, was

performed by welders qualified in accordance with AWS standard qualification tests. Government welding inspectors followed all operations in shop and field examining the radiographic films and determining the adequacy of the welds or the necessary repairs. The inspectors also qualified new welders engaged by the contractor and issued certificates to those passing the test.

HYDROSTATIC PRESSURE TESTS

The specifications called for proof hydrostatic pressure tests for the penstock and outlet pipe system after the completion of installation and prior to full concrete encasement of the pipe. It was specified that the pressure tests be performed in three stages and in a sequence covering first the outlet manifold, then both the outlet and penstock manifold, to be followed by a pressure test of the entire pipe system. Dished test heads were provided by the Southwest Welding and Manufacturing Company for that purpose.

The hydrostatic tests were performed essentially as specified, and the two sectional tests on the manifolds were entirely successful. In preparing for the test on the outlet manifold (which was performed on September 21, 1948), the flanged ends of the outlet pipes were closed with flanged test heads (the control gates were not in place at that time). Closure of the upstream end of the manifold was effected by a 15-ft test head butt welded to the end of the manifold. After the manifold was filled with water and properly vented, the required pressure of 275 psi was developed by a pump connected to the manifold. A calibrated pressure gage was used to indicate the pressure in the manifold. The test pressure was applied slowly and was maintained for a sufficient length of time to permit the inspection of all plates and welds.

After the installation of the penstock manifold, the test head at the upstream end of the outlet manifold was moved to the upstream end of the penstock manifold and butt welded in place. The downstream ends of the three penstock branches were closed with test heads welded inside the pipe. This second pressure test which included both manifolds, was performed on November 20, 1948, in a similar manner as the first test. Both tests were made by the installation contractor, J. A. Terteling and Sons, in the presence of Bureau inspectors.

The third hydrostatic pressure test was performed on January 4, 1950. This test included the entire penstock and outlet pipe system with the exception of the upstream plug section. Before making this test the dished head at the upstream end of the penstock manifold was removed and the 15-ft header was closed with another dished head. This head was lap welded into the header at the downsteam end of the tunnel plug. In preparation for the test, the pipe system was filled with reservoir water by means of a 6-in. supply line provided for that purpose. The water temperature was 41° F at the time. During filling the air was vented from the pipe system by an air vent located on top of the 15-ft header below the upstream test head, and through the by-pass lines of the ring-follower gates which had been installed before this test.

After filling, the pressure in the pipe system was boosted by means of an air-driven pump, the suction line of which was connected to the 6-in. supply line used for filling. The 4-in. discharge line of the pump was connected to the test head of Penstock No. 1. Two calibrated pressure gages of the nonrecording type were used during the test, one near the pump, and one on top of the 15-ft header just below the upstream test head. No recording gages were used dur-

Fig. 3 The facture in the pipe shell extended to stiffener rings at both ends, the resistance of which to the propagation of the crack changed its course

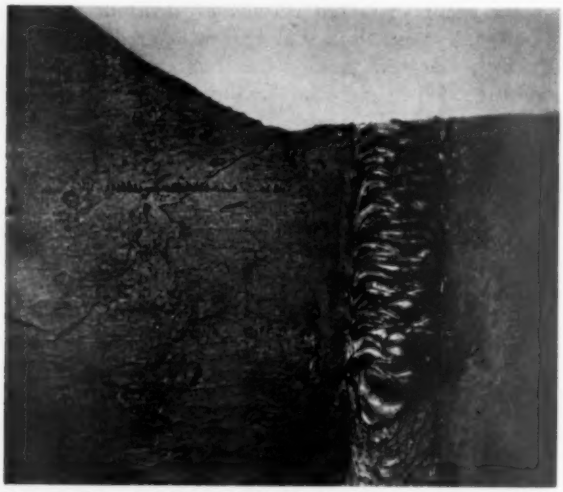


Fig. 4 Investigations showed that the fracture originated at this girth joint which was welded in place in the tunnel. The secondary crack branching off the main fracture indicates a point of stress concentration which may have been due to an undisclosed defect in the weld repair

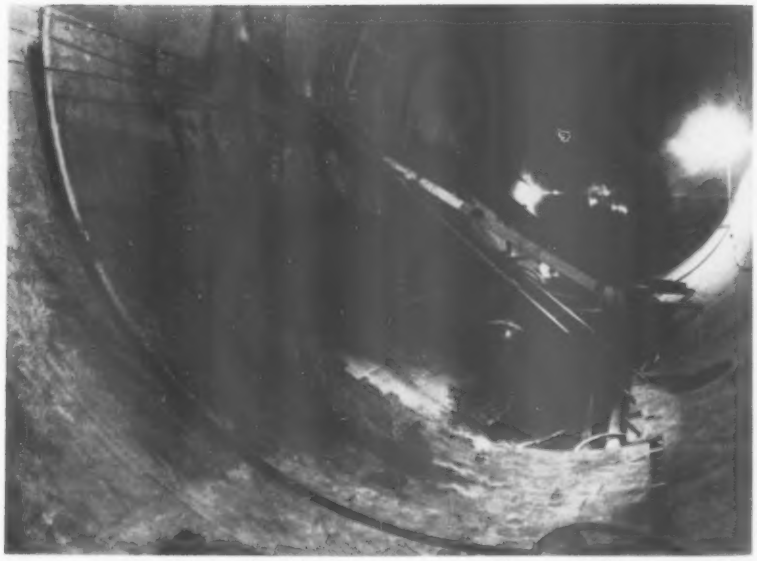


Fig. 5 Struts with turnbuckles were used to pull pipe shell into position before welding the new plates in place. By careful fitting and welding a good repair job was produced

ing the test. The test crew reported that the gages were compared at 80- and 120-psi test pressures and showed identical readings in each case.

PENSTOCK FAILURE

According to the test crew's report, failure in the 15-ft header occurred at a test pressure of 200 psi. A 50-ft long longitudinal crack having lateral end branches developed during the test. The fracture ran across three pipe sections (see illustration), which varied from $1^5/_{16}$ to $1^9/_{16}$ in. in shell thickness. One stiffener ring at each support was also fractured. Presumably the resistance of these rings to the propagation of the crack caused it to change its direction at the ends. The main fracture ran parallel to but not closer than about 5 inches from a longitudinal joint. It crossed four circumferential joints, one of which was welded in place in the tunnel. There were strong indications that the crack originated in this tunnel-welded girth joint marked No. 44. The shape of the fracture, the coarse weld repair made at the point of the joint, and the direction of chevron pattern in the fractured plate surface all indicated that the fracture originated at that joint.

Shortly after the failure a number of test plates were removed from the penstock header near the fracture. The plates and welds were examined, radiographed and tested in laboratories of the United States Steel Corporation and the Bureau of Reclamation to determine whether they included any defects which could have contributed to this brittle or cleavage-type fracture. No defects of any kind were found in the plate samples which could have caused the fracture and no reduction in area or necking was evident. This and the granular appearance of the fracture furnished further proof that it was a cleavage fracture.

The plate samples showed the following chemical properties, all in percent: carbon 0.16, manganese 0.52, phosphorus and sulfur 0.03, and silicon 0.16. Physical tests also indicated tensile strengths of 52,800 to 57,700 psi; yield points of 29,600 to 35,300 psi; and elongations of 38 to 42%.

Both the steel suppliers, one of the penstock fabricators, and the installation contractor had representatives at the project to investigate the failure and determine its cause. The two metallurgists representing the steel companies at this investigation, after a close examination of the fracture, arrived at the conclusion that the fracture originated at the repair weld in Girth Joint No. 44. Subsequent laboratory investigations of the repair weld furnished further evidence to support this conclusion. Radiographs made during installation showed that the weld repair was necessary because of incomplete penetration in the original weld. Photographs taken of the plate sample containing the repaired weld also indicated a small crack branching off the main fracture. This branch crack terminated in several small forks.

In view of our limited knowledge in the field of metallurgy and welding, it is extremely difficult to draw definite conclusions as to the cause of the penstock failure. Based on the available evidence, the brittle fracture in this ductile material resulted from the sus-

Fig. 6 Repaired header was hydrostatically tested at 150 percent of the design pressure and was proved to be safe. The pipe system was placed in operation in 1950 and has since given satisfactory service

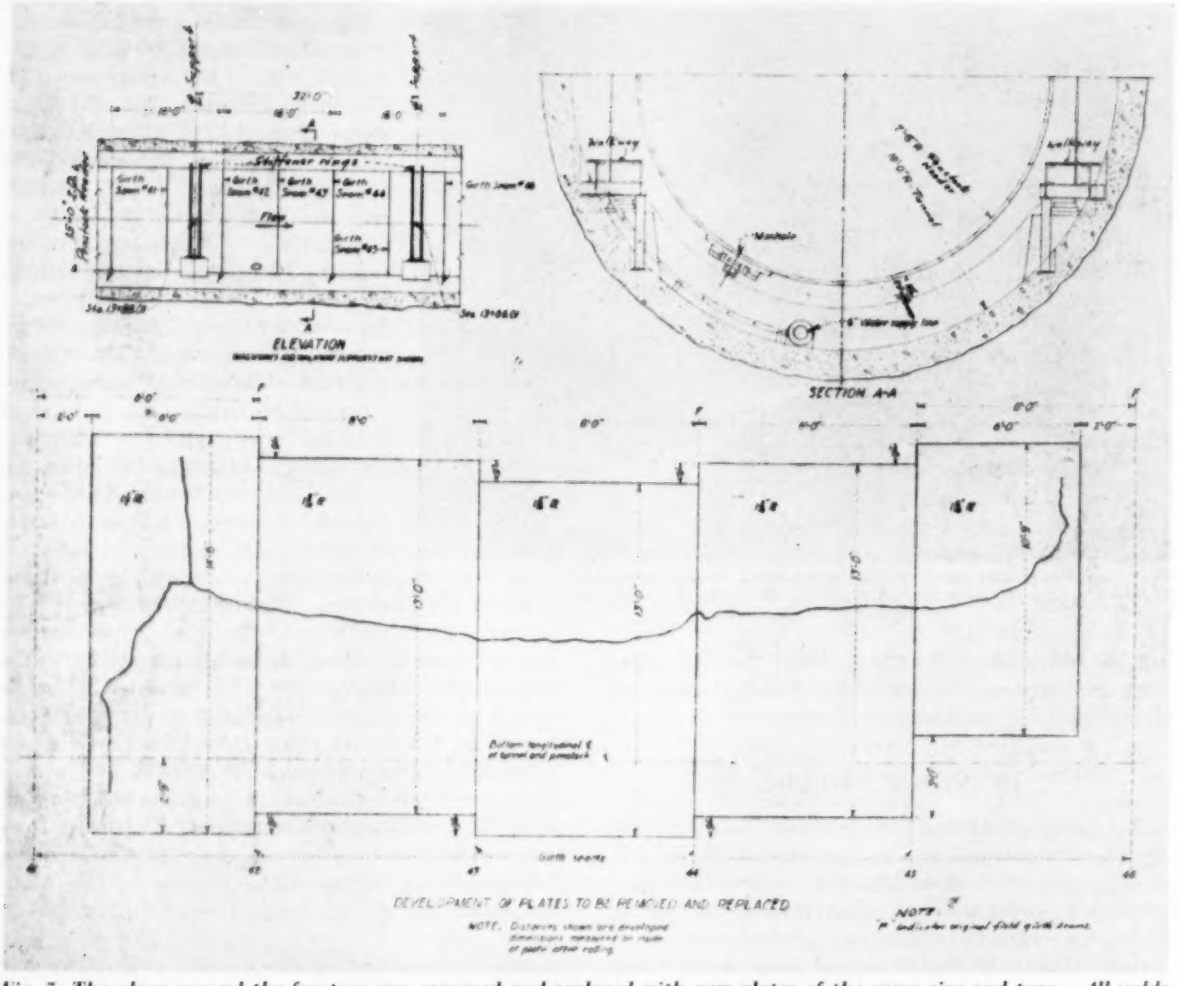


Fig. 7 The place around the fracture was removed and replaced with new plates of the same size and type. All welds were X-rayed and stress relieved

ceptibility of the steel plate to low ductility or brittleness when subjected to three-dimensional constraint (triaxial state of stress) in combination with a possible stress raiser occasioned by an undisclosed crack or other defect in Girth Joint No. 44. From the direction of chevron patterns shown in the fracture surfaces, it is concluded that the failure originated in this tunnel-welded girth joint. The heavy irregular beads applied during a weld repair of the joint near the line of fracture may have provided the notch effect and stress concentration leading to failure.

REPAIR OF PENSTOCK HEADER

With the spillway incompleted at the time of the failure, the penstock and outlet pipe system was the only means to divert the spring run-off. It was imperative, therefore, to complete the repairs at the earliest possible date. In preparation of this work the plates adjacent to the crack were removed by flame cutting. Plates showing excessive deformation which would be difficult to bring into circular shape were removed far enough from the crack to include such deformed areas. As shown in the illustration, the plates were cut so as to provide staggered longitudinal joints as required by the Code. The plates removed had an area of $463\frac{1}{2}$ sq ft. New plates of the same thickness, size, and composition were procured as the plates which had been removed.

The ruptured support rings at both ends of the crack were first jacked into position and welded together. the slightly deformed plates remaining around the opening were forced into circular shape by means of struts equipped with turnbuckles (see illustration).

The repair plates had been rolled into circular shape in a Chicago plant. Upon receipt at the dam they were moved into place on a skid running on a track which was installed above the header. After being lowered to the bottom of the tunnel the curved plates were fitted into the opening of the header and were beveled for 60 deg double-vee-type joints. Welding was done from both sides using a step-back method of welding. The outside passes, which were mostly overhead welds, were made first, then the inside passes

were deposited. All intermediate weld passes were peened; the peening was controlled by punch marks across the welds. Weld shrinkage was reduced to about one-half of the normal amount by peening.

After welding, the joints were fully radiographed and defects repaired. All repairs were radiographed to check the adequacy of the repairs. After the completion of radiographic inspection the repair welds were subjected to low-temperature stress relieving to further reduce residual welding stresses. This controlled heat treatment was performed under the technical supervision of an engineer. After stress relieving, the welds were again radiographed to check the effect of this heat treatment, and defects discovered have been repaired. The repaired welds were again stress relieved and radiographed to check the quality of the repairs.

A limited number of strain-gage readings were taken of the pipe shell in the failure area, before and after stress relieving. Readings on the plate midway between the welds indicated no material change in the longitudinal and circumferential stresses. Strain measurements along and across the welded joints showed that the stress changes induced by the low-temperature stress-relieving process were compressive in and adjacent to the welds. This indicated a relief of an equal amount of residual tension caused by welding.

By working two shifts a day throughout the week, the entire repair job, including radiographing and stress relieving, was completed in about 1 month. The question then arose whether the pipe system would be safe for the diversion of the spring run-off. As the reservoir level was steadily rising and the necessity for diversion became more pressing, there was no time to make preparations for a full-scale hydrostatic pressure test. It was decided, therefore, to make only an initial test under the prevailing reservoir head to prove the safety of the pipe system for diversion. This test was performed at a pressure of 100 psi, which was maintained for 6 hours to permit the inspection of all pipes and welds for signs of failure. As no leakage or failure was apparent at any point, the pipe system was released for diversion, which was accomplished through the five outlet pipes and hollow-jet valves. To make this diversion possible, a 12-ft-diameter opening was cut in the test head at the tunnel plug which permitted the flow of water into the header. The plates were removed by flame cutting in sizes to facilitate handling and rewelding into the test head prior to the final pressure test.

FINAL HYDROSTATIC PRESSURE TEST

As diversion through the penstock and outlet system was terminated on August 1, 1950, arrangements were made to subject the system to a full hydrostatic pressure test to prove its safety during operation. This test was performed in accordance with detail instructions prepared by the Chief Engineer's office of the Bureau of Reclamation and under the supervision of that office. A new centrifugal test pump was procured. Pressure gages of both the recording and nonrecording type, a fluid pressure scale, a number of electrically activated pressure cells, and thermometers were installed. This instrumentation made it possible to obtain a complete history of the pressure applied and the temperatures prevailing during the test. Strain gages were also used at strategic points to ascertain the stresses during the test.

Before filling the pipe system, the 12-ft-diameter opening which had been cut into the upstream test head to facilitate diversion was welded up again using the plates previously removed from the head. The plates had been stored in Penstock Branch No. 2 during diversion, as they were too large to pass through the manholes. An attempt was made in this test to comply with the Code's recommendations to use water having a temperature preferably not less than 60° F. The water actually used had a temperature of 68° F, and was drawn from the reservoir surface by means of a temporary pipe line and pump.

While the pipe system was being filled with water from the reservoir, the air was vented through openings on top of the header and through the upstream manhole which was left open during the filling operations. Pressures above the reservoir head were boosted in stages by the test pump, first to 100 psi, then to 150, 200, 237½ and 275 psi. Before each boost, the pressure was lowered to 100 psi. A loading rate of 100 psi per hour was adopted, except that in increasing the pressure over the previous increments a loading rate of 25 psi was used. The maximum test pressure of 275 psi was reached on August 14, 1950, which was held for 3 hrs without any leakage or sign of overstress in any portion of the system. Shortly after the test, the penstock and outlet pipe system was placed in operation and has since performed satisfactorily.

Figure 1

Allen County War Memorial Coliseum

by Ralph E. Coblentz

THIS very sports-minded community rejoiced in the completion and dedication in Sept. 1952 of the War Memorial Coliseum, by the Allen County Commissioners, near Fort Wayne, Ind.

This building was designed to serve the largest possible number of groups of people, from those interested in all types of sports, to the farm groups with the county fairs, cattle shows and 4-H meetings, etc. These requirements gave rise to the decision to build an exhibition hall in the basement and a sports arena on the first floor. The Coliseum has 7150 permanent seats, with additional temporary seats to total 8900 for ice hockey, 10,420 for basketball, and slightly more for boxing and wrestling.

Taking advantage of the large tract of land available, ample auto parking space is provided for the largest crowd that may attend any function. Also, the south portion of the site is lower, and an outside grade entrance and drive-in to the exhibition hall was provided. This exhibition hall area will be available to customer parking for arena floor events during bad weather as an additional revenue source.

The arena floor is of reinforced concrete flat slab construction 9 in. thick, supported by 18-in. diam concrete columns on 27-ft centers. The clear height in the exhibition hall is 16 ft 5 in.

Permanent concrete bleacher construction surrounds the entire arena floor. To conserve space in the corridors and ramps leading to the upper bleacher seating, the normal system of using a concrete column to support the outside ends of the bleacher stringers had to be eliminated and some scheme devised to connect the permanent rigid bleacher framing to the rigid frame which must be permitted to move with loading and expansion and contraction due to temperature changes. To meet this problem, a link hanger was devised to permit ample movement of the frame without undue stresses being induced in the members concerned. This link hanger was used for both the upper bleacher framing and the mezzanine floor beams.

One of the outstanding features of this Coliseum is the long span, all-welded rigid frames supporting the roof construction. The frames are spaced at 27 ft center to center and span 224 ft center to center of the column portions of the frame. Each frame is built up entirely of plates with all shop fabrication done by welding and all field splices also welded. The frames were shop fabricated in five sections. Each section was set in a jig and flange plates welded to the web plate by a continuous weld. Shop welding was done by automatic machine using the new hidden arc-welding process.

The column sections were composed of a web plate 55 x $^5/_8$ in and flange plates. 18 x $2^1/_2$ in. thick. The

Ralph E. Coblentz, is Chief Engineer, A. M. Strauss, Inc., Fort Wayne, Ind.

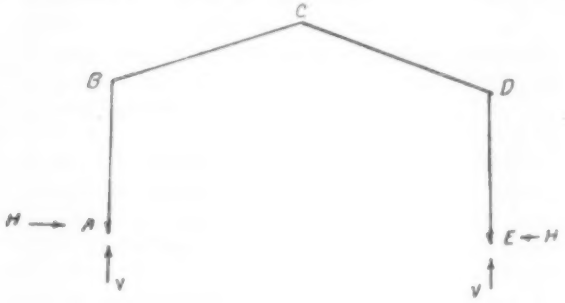
rise from the base plate to the top of the knee was 54 ft 10 in. Radius of the haunch at the knee was 21 ft. The five sections making up a complete frame consisted of two column sections, two rafter sections and one center section. The rafter sections were composed of a web plate 72 x $^5/_8$ in. and flange plates of 18 x $1^1/_2$ in. thickness. The radius of the haunch at the center of the span was 50 ft. Total weight of one frame is 68 tons.

The rigid frames are tied at the base by two 2-in. diam tie rods with upset screw thread ends for turnbuckles at each end. The tie rods were field welded from 20-ft sections and accurately placed on the forms used for supporting the concrete flat slab arena floor. These rods were greased and wrapped with sisal paper to prevent any bond between the concrete floor slab and the tie rod. The rods were positioned to the exact center of the 9-in. flat slab floor. In making the field welds the rods had to be raised slightly at the point of the weld to allow for the draw when the weld cooled, pulling the rods back to a straight line.

The rigid frames were set on concrete piers 36 x 76 in. A pocket 6 in. deep was left at the top of the pier for shimming and grouting the frame base. No provision was made for a positive hinge at the base, although it is designed as such. Since the dead load which is the greatest portion of the load, was on the frame before any grouting of the vase was done, it is assumed that the rotation of the base would be so slight as to preclude any expensive hinge details. Also, the long column lengths are sufficiently flexible to permit rotation of the knee.

Bracing was provided at each knee to stabilize the haunch which was 12 ft 3 in. deep at the deepest section. Also vertical bracing to stablize the haunch at the center of the span which was 8 ft 3 in. deep on the center line. Intermediate vertical bracing was spaced at 30 ft centers along the frame span. Horizontal "X" bracing was placed in alternate bays.

Frames were designed to support a dead and live load of 46 psf of roof construction which consisted of 4-in. thick precast perlite slabs spanning 6 ft and supported on 12-in. purlins. Precast perlite slabs were chosen for the roof construction because of their combined uniform insulation value, strength, acoustical properties, and appearance since the underside is to be left exposed and unpainted. Ease and rapidity of erection is another point in favor of the precast slabs.



Design moments, shears and reactions were calculated separately for each of the following loadings and then a logical combination made to produce the maximum moments, shears and reactions.

(*a*) Uniform dead and live load over the entire span.
(*b*) Wind load on wall.
(*c*) Wind load on roof.
(*d*) Bleacher and mezzanine floor loads.
(*e*) Temperature changes.
(*f*) Concentrated load at center of span.

The combination of the above loads, which gave maximum knee moments, maximum center moments and maximum tie rod tension can be seen from the table given below (an increase in temperature would not occur with maximum snow load).

The knee which is the critical point of a rigid frame was designed for a maximum moment of 69,360,000 in.-lb and an unbraced length of 30 ft. Maximum tie rod tension was 110,700 lb.

Erection of these long span rigid frames posed many problems. First, the frames had to be erected on a slab over a full basement which had a limiting live load of 330 psf. Second, all field splices were 100% welded with dovetail splices. Third, location of hoisting equipment. Fourth, an assembly procedure to hold alignment of rafter sections for field welding and a welding procedure for the field splices to eliminate distortion.

The system followed was to place each column section in its vertical position. Then a track, consisting of two 10-in. I beams 12 ft on centers, placed on the floor slab between bents and running the full width and beyond the building on the truck unloading side of the building. On this track was 3 sets of towers made up of 2 x 2 x $^1/_4$ angles welded with wheels at the base for running along the track. One set of towers was for each of the three frame sections. The assembly was all from the same side, so a frame section was set on the towers and pulled along the I beam track until each of the other sections was in place. The top of each tower contained stiffening uprights with both horizontal and vertical screw jacks for adjusting and aligning

Values in Ft.-Kips

	MB	*MC*	*MD*	*HA*	*VA*	*HE*	*VE*
Uniform load	−5000	−2790	−5000	94.3	193	194.3	193
Wind on wall	− 451	− 116	308	−22.8	− 3.4	5.8	3.4
Wind on roof	− 497	− 90	435	−96.	− 5.4	8.2	5.4
Center load	− 37	− 52	37	0.8	1	0.8	1
Bleacher Load	− 23	− 17	23	1.6	36	1.6	36
Decrease in temperature	− 111	− 180	111	− 2.1		− 2.1	

the members preparatory to welding the field splices. See sketch for arrangement of towers, rigging, bracing and adjusting clamps. These bent support cars were designed to hold the various frame sections in the same relative positions as they would be when erected in the structural frame. Design of these bent cars and their location under the various sections was planned to fit in properly with the requirements of the hoisting equipment connections to the assembled frame.

It was of special importance to keep these frames hanging as near a perfect vertical position as possible when hoisting and fitting into the column joints, therefore, a rigid "H" beam lifting frame was designed to extend slightly above the center peak of the frame (note sketch). This placed the entire frame weight below the load pivot point thereby causing the load to hang in the ideal vertical position, also overcoming the tendency for the frame to rock or roll over sideways.

To prevent undue flexing or whip of the long center section during raising, a diamond-shaped cable truss arrangement was used which fastened to each "H" beam lifting frame (see sketch).

To maintain an efficient production sequence in the erection of the frames, the two gin poles were arranged so they could be boomed up or down similar to a derrick boom. This permitted the placing of the erection bent cars and tracks in proper position for loading the next frame while the poles were holding the hoisted frame for the welders and assembly of bracing steel. When the load was hoisted out of the bent cars, the poles were boomed out approximately 42 ft from vertical position, then while the load was hanging in mid air, they were boomed up to approximately 27 in. from the vertical position, and at this point the frames were hoisted and connected to the column tops.

Welding of the two rafter sections to the center section was done by two welders working one to each side of the joint and duplicating their welds closely in order to keep distortion to a minimum. The welding time required 4 to 5 hr for the two men, totaling 8 to 10 man-hours for this connection.

Welding of the rafter sections to the top column connections was done by two welders working in the same manner as for the above splice. The welding time required for this splice was 9 to 10 hr for two men, totaling 18 to 20 man-hours per splice.

The procedure for welding these field splices was worked out by the Pittsburgh Testing Laboratory and the welding foreman for Machinery Co., of Bowling Green, Ky. The erectors: First tack welds were made on the web, welding 6 in. then skipping a 6-in space, then repeating for the length of the web. Next the web was tack welded to the flange just behind the "V." The flanges were then welded with two passes using $^{1}/_{32}$-in. rod. Then three passes using $^{3}/_{16}$-in. rod and finished with $^{1}/_{4}$-in. rod. The web was next with the remaining 6-in. spaces welded with $^{5}/_{32}$-in. rod to complete the first pass, then another pass with $^{5}/_{32}$-in. was made the full length of the web, then the web was completed with $^{3}/_{16}$-in. rod. Last the 12-in. length of web fitting against the flanges was welded with the same procedure used on the other part of the web. An attendant was on constant duty at the welding machine so as to make frequent changes necessary on the welding machine current and voltage to correspond correctly with the size rod being used.

The best erection time for one frame that could be obtained with good weather conditions was three working days. A great deal of bad weather was encountered and much of the structural steel work was erected in very cold weather during the winter of 1950. From a study of actual costs and normal profits allowed, these large frames could be erected for approximately $3400 per frame, or $50 per ton.

Another feature of the design was a system of catwalks, one through the center of each bay extending from side to side of the building, and a connecting catwalk along each side. These catwalks will be used for servicing lighting, heating and ventilating equipment suspended from the roof construction.

The entire structure rests on a hard, well-compacted soil for which a footing design load of 8000 psf was used. The arena floor slab was designed for a live load of 330 psf and in addition to this live load, an ice floor load composed of 4 in. of fibre glass insulation, waterproof membrane, and 3 in. of lightweight concrete in which the brine pipes are embedded, and finished with 3 inches of sand and gravel concrete.

Concrete for the structure was divided into two types. Type "A" contained a minimum of $6^{1}/_{2}$ bags of cement per cubic yard of concrete and required an average 28-day compressive test of 4200 psi. This type of concrete was used for all columns, slabs, beams, bleacher construction, stairs, and ramps. Type "B" concrete contained a minimum of $5^{1}/_{2}$ bags of cement per cubic yard and required an average 28-day test of 3500 psi. Type "B" was used for footing, walls, slab on ground, rigid frame piers, retaining walls and sidewalks.

All concrete is being supplied by the two local ready-mix plants. One plant is using washed and graded gravel for coarse aggregate and the other plant is using crushed limestone for coarse aggregate. The tests, of which there have been some 275 6 x 12-cylinders to date, show approximately the same strengths using either coarse aggregate.

Total quantity concrete when completed will be approximately 13,000 cu yd. All concrete mixes were designed, and controls and test cylinders made and tested by Wm. Droege Testing Laboratory, Fort Wayne.

Total structural steel tonnage was 1246 tons. All structural steel was fabricated at the Fort Wayne Structural Steel Co., located approximately $1^{1}/_{2}$ miles from the building side. Contract price for the 1246 tons of structural steel was $230,000 FOB job site. All shop and field welding was done by qualified welders. Pittsburgh Testing Laboratory ran the welders' qualification tests and inspected all shop fabrication and field erection.

The Martin Erecting Co. was awarded the contract for steel erection, but they, in turn, sublet the erection of all heavy work including rigid frames, column bracing, etc., to Machinery Co. of Bowling Green, Ky., of which T. H. Covington is president. Mr. Covington personally devised the scheme of erection work.

Hagerman Construction Co. has the general contract at a price of $1,925,931.

Electrical contract is for $173,209; the plumbing and heating contract for $340,504. Equipment for the Coliseum not included in the above contracts was purchased separately on the following bids: portable basketball backstops, $1750; platforms for temporary grandstand seats, $31,722.10; 2700 folding chairs at $3.17 to $9.85 each.

The Coliseum was designed by A. M. Strauss, Inc., Architects-Engineers, Fort Wayne, Ind., for whom the writer is Chief Engineer and was designer of the rigid frames.

The Spot Welding of Magnesium with Three-Phase Low-Frequency Equipment

Discussion by J. J. Riley

The authors of this paper have presented a factual analysis of the spot welding of magnesium for 0.064 in. thickness. It is an excellent piece of work and should clearly establish the fact that magnesium can be welded on three-phase equipment provided proper equipment and welding technique are used.

In production applications it is desirable to make the welding results—that is, the degree of quality—as independent of the variation of any welding variable as great as possible. If additions in welder machine design and electronic welder control design accomplish these results, such additions should be justifiably added.

The writer feels that this paper indicates clearly that satisfactory spot welds can be made on single pressure at a value of 2500 lb.

In this case the weld current could vary from approximately 48,000 to 54,000 amp (more than 10%) and still produce sound welds.

However, if dual pressure is used (forge force), provided that initial pressure is not too low, the technique becomes less sensitive in that good results could be obtained from forces as low as 1200 lb. initial force and 2400 lb final up to 1600 lb initial force and 2500 lb final force. It can be readily assumed that the 2500 lb limit could have been increased without changing weld quality. Consequently, the addition of dual pressure allows more flexibility to overcome slight pressure irregularities encountered in day-to-day production.

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Paper by P. Klain, D. Knight and J. Thorne was published in the January 1953 issue of THE WELDING JOURNAL, pp. 7 to 18.

While affecting the shear strength somewhat (reducing it for the same spot diameter), the addition of postheat widens the pressure range and current range in which acceptable welds could be made still further.

This sequence of additions to the welding technique to provide a more flexible weld schedule is duplicated on work in spot welding aluminum alloys and at present is accepted as the most satisfactory manner to make welds in light alloys.

As an indication of what the combination of dual pressure and postheat can afford in allowing flexibility of combination of welding variables, the following data on spot welding magnesium (AN-M-29), taken from qualification runs on a dry disk rectifier welder (Tri-Phase) in an aircraft plant, is presented:

Thickness, in.	*Weld time, cycles*	*Postheat time, cycles*	*Forge delay, msec*	*Initial force, lb*	*Final force, lb*	*Av. shear, lb*
0.020–0.020	1½	1	10	300	600	146
0.064–0.064	3½	3	30	700	1600	608

NOTE: 3-in. radius electrodes used on 0.020 and 4 in. radius electrodes on 0.064.

It should be noted that only 1600 lb final force was used on 0.064 in. thickness yet, by the addition of postheat, crack-free welds were produced. It should also be noted that the shear strength is less than the general average in the above paper.

One major problem for the acceptance of the spot welding of magnesium must still be solved. This problem is surface preparation. In the work in the above paper and other applications, it was necessary to first chemically clean and then mechanically clean the samples a few minutes before welding. To the writer's knowledge there is not any chemical cleaning process (such as used in aluminum welding) which will satisfactorily prepare the surface of magnesium for spot welding.

The writer hopes the authors will continue their work on other gages to extend the knowledge on spot welding of magnesium.

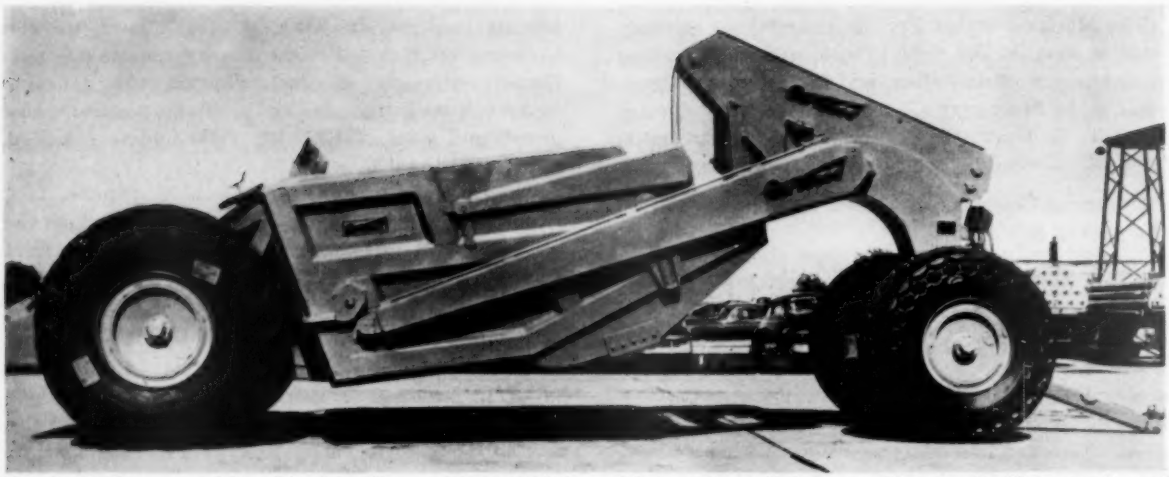

Fig. 1 Cable-operated Gar Wood earth mover typical of those fabricated largely by arc welding in the Mattoon plant of Gar Wood Industries, Inc.

Manual Hidden Arc Welders Halve Time on Earth Mover Components

Application of automatic and semiautomatic submerged arc welding in the fabrication of heavy earth-moving equipment

by William T. Potter

EARTH-moving equipment manufactured at the Mattoon, Ill., plant of Gar Wood Industries, Inc., has long been assembled largely by arc welding. Most of the components are fabricated from steel plate and strong joints are necessary, partly because stresses imposed are high and severe usage is the rule. Until recently, although some automatic arc welders have been used especially for straight seams, a majority of welds were made by hand equipment because it was readily adaptable to the contours and in the locations involved.

Regular hand open arc welding yielded good welds but was slower than desired, often resulted in excessive warpage and spatter added to cleaning costs. In consequence, when manual hidden arc welding machines (so-called "squirt" welders) became available, they were given extensive trials and proved themselves so readily adaptable and so economical that their application has now been extended as rapidly as the new Lincoln machines could be obtained.

Actual welding with semiautomatic welding has cut welding time in most cases by 50% or more and, in some cases, over-all time per weldment has dropped to about one-third of that formerly needed partly because of decreased warpage and of shorter set-up time and in part because freedom from weld spatter has reduced cleaning time greatly. In addition, excellent penetration is obtained and welds are of more uniform excellent quality than those of ordinary open arc welding. In addition, less training is required to develop skill with the units.

Quality equals and speed in squirt welding is about on a par with that on fully automatic arc welding done in this plant, but the saving in set-up time over automatics is considerable. This is because in general the welding can be completed in tacking position and workpieces need not be moved to bring it into the particular location relative to the welding head and track that is necessary in the fully automatic machines available. Use of the latter is continued chiefly for straightline welding on certain jobs, but this is largely because the limited number of squirt welders available is still below that needed.

Slower welding and certain variables in open arc welding often result in more warpage than in squirt welding and this involves more straightening with extra expense on this score. In squirt welding in this plant, it has been found possible to predict the amount of warpage and thus to counteract it by correspondingly bowing the parts. This requires the use of special

William T. Potter is Superintendent, Mattoon Plant, Gar Wood Industries, Inc.

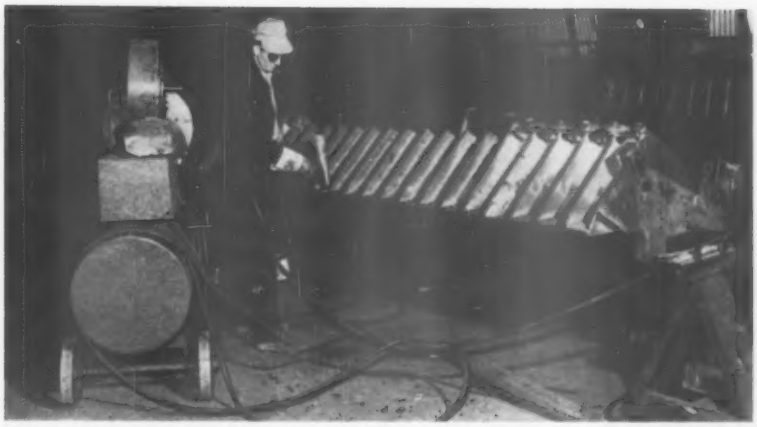

Fig. 2 Using a manual Lincolnweld hidden arc unit to fasten the ends of V-shaped reinforcements of a mold board for an earth mover. A trunnioned fixture facilitates quick location of the work in most convenient position

cambered fixtures but when they are correctly applied, the camber allowance will result in the workpieces coming back to unbowed shape when released from the fixture after squirt welding. In these cases little if any straightening is needed and the resultant savings soon compensate for special fixture costs.

A typical Gar Wood cable-operated earth mover appears in Fig. 1. This also shows some of the weldments including one of the side assemblies made up from flat plate to which channel shapes are welded to form boxlike reinforcements. Not visible in Fig. 1 is the mold board that supports the cutting blade, both of which are weldments that include many reinforcements arc welded in place. Figure 2 shows a mold board to which reinforcements are being squirt welded using the portable Lincoln machine at left. This feeds $^{5}/_{64}$-in. wire from a reel through the welding gun that holds granular flux.

V-shape parallel reinforcements are welded along the contour where they fit flat plates, the ends presenting a series of points. By supporting the assembly on trunnions, it is easily set at any angle favorable for making the $^{1}/_{4}$- and $^{1}/_{2}$-in. fillet welds rapidly, using 375 to 400 amp. Hand welding required about three times as many man-hours and resulted in much more warpage.

Another view of this assembly, tilted to show in Fig. 3 another side from that appearing in Fig. 2, indicates how much welding is needed on this mold board. Some hand welds including many tack welds are required but by having the work on trunnions, it is easily brought into position where a large portion is done with the squirt welder with large savings in time.

Side frames for scrapers are welded in setups like those shown in Figs. 3 and 4 using low benchlike fixtures whose steel top plates are $1^{1}/_{2}$ in. thick and are heavily reinforced below. Instead of using a flat bed its upper face is purposely given a camber. Spanning the heavy plate is a bridge beam supported on wheels under upright frames at each end so that the bridge can be moved easily to any point above the bed.

Fig. 3 Another side of the mold board assembly being welded in the same trunnioned fixture shown in Fig. 2. Nearly all seams can be brought to horizontal position where the granular flux will keep the arc covered

Fig. 4 Special set-up bench with cambered top employed to hold earth mover side frame components in position while tack welding. A hydraulic jack under the movable bridge is used to clamp edges of channel reinforcements against the plate on the bed

In fabricating a side frame a flat plate precut to required contour is first laid on the bed. Preformed reinforcements then are laid on the plate and a hydraulic jack is used under the beam to spring the reinforcements and plate so that they assume the same camber as the bed against which they are pressed. C-clamps are bolted to the bed at intervals around the edges of the plate and the latter is fastened down to the plate by driving wedges under the C-clamps.

After reinforcements are applied the jack is used to

Fig. 5 After components of this side frame are tack welded as in Fig. 4, the bridge is rolled back and leaves all areas clear for making hidden arc welded seams. Regular hand arc welding is done only on seams too steeply inclined to hold welding flux used in hidden arc welding

spring them so that their lower edges lie tightly against the plate, after which tack welds are made with hand equipment as in Fig. 4 to hold the reinforcements in place. When tacking is completed the whole structure is bowed to bed camber and the bridge is rolled out of the way.

Then another man, using a manual hidden arc unit as in Fig. 5, completes most of the previously tacked seams including all that are horizontal or not too steeply inclined to hold the flux. Only welds that are steeply inclined are made by ordinary hand welding. As the welds are all above the side plate clamped to the bed, they tend to cause warpage but after welding is completed and wedges are removed to free the weldment, the plate becomes substantially flat. This is because the stresses applied in clamping to a camber counteract those set up in welding, the amount of camber chosen having been determined by experiment to yield the required final result.

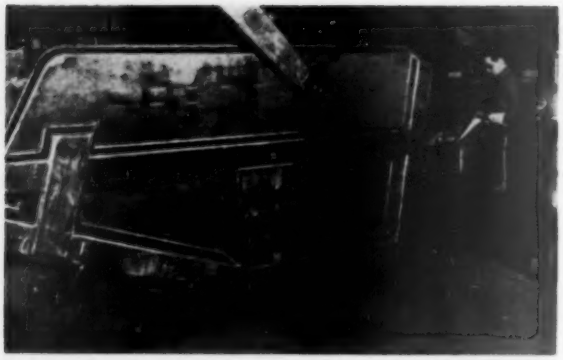

Fig. 6 Car Wood earth mover final assembly nearing completion. Each side frame previously assembled required 174 ft of welding, chiefly by semiautomatic welders

Two nearly duplicate benches are employed for making the right and left side frames, one man working at each. One makes all the setups and does tack welding and then the other takes over and makes the squirt welds and the short hand welds to complete the job while the second man is completing the welding. The manual hidden arc machine is used for making both the hidden arc as well as the open arc welds. The first man prepares another setup on the other bench. In this way neither man interferes with the other and each becomes expert in doing his part of the job. Two men produce a pair of side frames each needing 170 ft of welds in 8 hr where with hand welding alone, it took about 40 man-hours to obtain as nearly equivalent results as were possible.

Present methods effect about a 40% time saving that soon paid for the fixtures. In addition welds are better and distortion, which was hard to correct previously, is practically eliminated; hence, there are gains on all scores. Above comparisons do not include the time saved in cleaning which is much less because weld spatter that occurs in hand welding is avoided with the hidden arc in squirt welding.

Figure 6 shows a side frame after it is installed on an

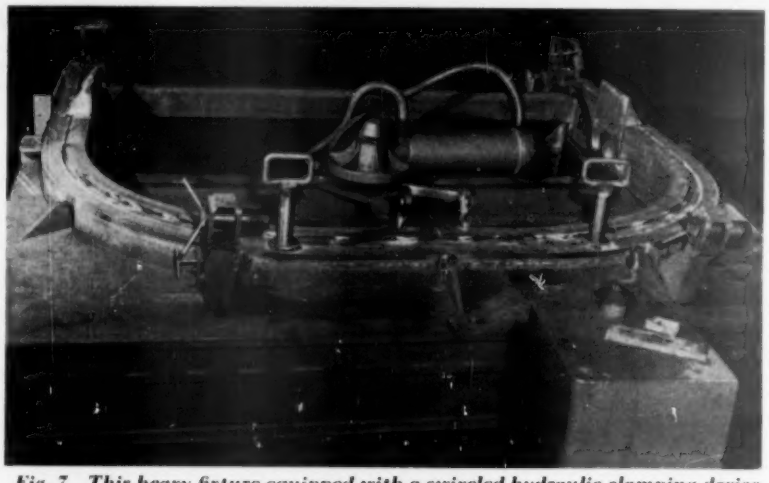

Fig. 7 This heavy fixture equipped with a swiveled hydraulic clamping device, is used effectively in holding arched channels and other components in correct position while they are tack welded

Fig. 8 Two men, each using a manual hidden arc welder, start at the top of this arched yoke and work around the arch in making fillet welds that join reinforcing plates to the inner faces of the facing legs of rolled channel members

Fig. 9 Close-up showing the making of welds around the arch of the yoke that is also shown in Figs. 7 and 8. Two passes are required to produce some heavy fillet welds needed in this assembly

earth mover and indicates the extent of welding done. This illustration makes it apparent that the squirt welder is useful too in making portions of the final assembly as it is employed after various major subassemblies are in place.

Another major weldment is an arch-shape yoke in which the two major components are 12-in. channels, the bowed portions having been formed in rolls to semicircular contour. Webs on these channels are $^1/_2$ in. thick and legs face each other. Around the arch they are joined by plates inside the legs whose edges are welded to the plates and form a box section. Where the arch ends the edges of the channels meet and are joined by welding; hence, straight parts also have a box section.

Heavy tubes are set in place in holes through legs of the outer channel and are welded in place. Other fittings located by pins are welded at and near the open end of the assembly but there is a cross channel between the straight portions of the inner channels that acts as a spacer. This cross member also strengthens the assembly which is subjected to heavy stresses in service. Formerly welding was done largely by regular hand welding and it was difficult to avoid as well as to correct warpage subsequently.

Now the job is done largely in the heavy fixture shown in Fig. 7, the plate at the arched end being $1^1/_2$ in. thick and cut to a semicircle that fits the outside of the weldment. Below the plate and along four sides of the fixture are channels on which brackets and other locating elements are mounted. This frame is reinforced by a cross beam and a longitudinal beam that comes together at the center of the arch radius. There, is a heavy vertical pin that supports a hydraulic cylinder arranged to swing horizontally around the pin.

On the outer end of the ram in this cylinder is a head that swings inside the arch and can be set along any radius. When forced outward by hydraulic pressure, the head presses against the inner channel, forces it into correct relation with the outer channel and acts as a clamp. This aids greatly in making the setup and in holding the inner channel at correct distance from the outer one, especially while tack welds are made. The outer channel is located by the fixture and by pins that pass through holes in the vertical tubes within the arch. It is estimated that by use of the fixture the setup time which required 36 man-hours before has been halved.

Once the components of the unit are correctly located and are tack welded in proper relative position the pins are removed and the assembly is set on horses for final welding as then the structure is stiff enough in itself to resist significant distortion during final welding. This is done as far as possible (about 60%) by squirt welders as shown in Figs. 8 and 9. In joining the edges of channel legs to the plate tacked inside the legs, two welders start at the center of the arch as in Fig. 8 and work outward.

Double beads are laid down to form the arch fillets because of the thickness of the sections joined and be-

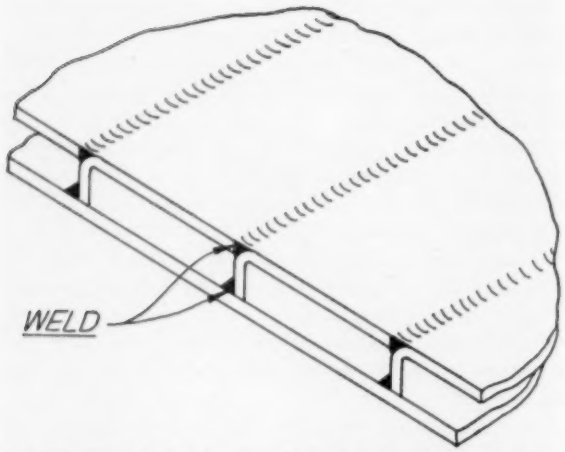

Fig. 10 Sketch showing a section of the double-wall structure produced by automatic arc welding angles to a plate. As welds are all in straight lines, an automatic works well; setup requires more time than for manual hidden arc welding

cause large fillets are needed for high strength. In the closeup, Fig. 9, some of the welds still partly covered by fused flux are shown along with the welding gun and the unit that supplies current and feeds wire to the torch gun.

Automatic welders are still used in this plant, especially for making straight welds along the edges of angles having unequal legs of which the shorter ones are welded to a plate as indicated in the sectional sketch, Fig. 10. Subsequently, the edges of long legs are welded to the angle bends, making, with the plate, a double-walled structure stiffened at intervals by the short legs of the angles.

Excellent and fast welding is done in such setups but considerable time is required to position the work in relation to the head and its track. For this reason squirt welders were tried with substantial saving in over-all time because it is so much quicker to bring them to the work than to move the latter into an automatic welder.

As the squirt welders were needed elsewhere, however, this job is still being done on automatics but is scheduled for conversion to squirt welding when extra equipment becomes available. Because welds in this assembly are all on one side of the plate, the assembly tends to bow if produced on a flat bed. So a cambered bed is now used, the camber being just enough to counteract the distortion and yield weldments that are flat as required without straightening.

Besides the welding already described much other work of a similar nature is done on other parts, squirt welders being applied wherever possible or to the extent that they are available. Although most work is done on day shifts, wheels are being squirt welded at night using a rotary fixture. This is done largely because all squirt welders available are kept in constant use during the day shift.

Operational Controls

by Donald C. Wright

THE title of this article, when considered from the standpoint of an industrial enterprise, involves a number of individual phases pertaining to the general objective of not only supplying satisfactory output to customers, but also insuring economic security to its own bank account. Accordingly, let us consider a few of these basic controls that are essential to the attainment of these desired ends such as Production Control, Scheduling and Planning, Budget Control, Cost Control and over-all Organizational Control. Of these, the last mentioned involves merely the distribution of the various functional responsibilities among such group leadership break-up that the size of the enterprise may make essential, while at the same time providing proper coordination between all, an accurate, up-to-date showing of their individual status.

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Generally speaking, proper organization provides the segregation of industrial controls into the four basic sections of engineering, sales, operations and finance, with leaders of each under the over-all supervision of the general management.

The exact composition and make-up of these group activities, of course, depends upon the size and nature of the particular business, but their respective responsibilities are easily recognized from the general titles cited.

Now, as we consider the various controls which any industrial establishment needs to insure maximum income, we do not want to be led astray by the interpretation of the word control by our national administration, which substitutes political expediency for actual efficiency. The real purpose of controls is to insure full compliance, in all phases of operations, with standards of performance and the constant alertness to any possible variations from such standards through changes in materials, facilities or other matters.

By way of illustration, let us take a look at a few of the major procedures in the so-called control class.

Of these, Production Control, Scheduling and Planning, Budget Control and Cost Control are the four that are, probably, of greatest importance in providing efficient performance of actual operating functions—such as meeting production and delivery schedules, avoiding delays in development programs, fully utilizing facilities and attaining maximum output before increasing capital investment, organizing and operating procurement activities to insure adequate material supplies—while avoiding excessive inventory investments; reducing both direct and indirect costs, spoilage, rework and customers' complaints.

PRODUCTION CONTROL

In order to effectuate efficient production control, certain preliminary study is required to provide the following basic determination of operating data:

1. Economical manufacturing and purchase lot sizes for all production items.
2. Time required to replenish each item.
3. Minimum stock required to maintain deliveries during the period of replacement.
4. A running record of all requirements.
5. An up-to-date record of all stock on hand.
6. An up-to-date record of stock available, which is the most important column in the record since it controls the order point and reveals the need for replenishment at the earliest possible time.
7. The order point, which is automatically signalled when the minimum on any item has been reached. Barring unusual conditions, the replenishment order will be completed before the minimum stock is exhausted.
8. The finish dates of production orders will be determinable from the data on quantity available and monthly consumption, as shown on the inventory record.
9. For each department there must be a schedule of all work ahead, for each operation, upon which they can assign the work to the operators in the order desired by the Production Department to insure completion before shortages occur.
10. A so-called load record that is always current and which will show:
    (*a*) Excessive loads in time to permit corrective action before the situation becomes serious.
    (*b*) Approximate percentage of capacity currently in use or scheduled, making it possible for management to determine delivery dates on any new business.

SCHEDULING AND PLANNING

Once the foregoing data have been compiled and a systematic procedure set up for maintaining it, not only will better operational controls be effectuated but also a reduction in inventory and charge-off for obsolescence, greater store room efficiency through reduction in back orders, and improved customer good will because of more prompt and complete order filling.

Like any other productive activity the various control procedures mentioned require both man power and equipment. Typical of the latter is the inventory card which carries the following headings: Monthly Requirements; Set-up Cost; Piece Cost Over and Beyond Setup; Lot Size; Time Needed to Make or Purchase; Minimum Stock Quantity. At the bottom of the card are listed the part or assembly number and name and the storage receptical identification number.

On the face of the card are listed the following columns: Quantity of Order, Received, Required, Available, Delivered, On Hand. In operation these various columns records are maintained by continuous entries from purchase orders, shipping records, receiving reports, stores requisitions, production schedules and reports of item production.

The reporting of these various basic items of information is maintained by means of an office routine whereby the various forms mentioned in the preceding paragraph are circulated through and recorded by the clerical unit responsible for maintaining this fundamental record. By careful observation of conditions as revealed by this most important tabulation all needs for action of any sort by the production or supply agencies of the concern, are constantly made apparent, and the proper steps can be taken to insure such action.

Naturally, no constructive evaluation of any reported status can be made without there being a definite pattern provided for comparative purposes. Therefore, the second of the four major controls cited at the outset of this article, namely Scheduling and Planning, becomes important. The title of this activity is fairly self-explanatory, but a few of the essentials are worth mentioning. For example: How can any project be scheduled and planned without full recognition of the final completion dates of the various sales items and the operational capacities of the plant facilities?

Accordingly, a thorough detail study of each individual manufactured unit, in terms of facilities involved in its production and the operational time which it requires to complete each step in its processing, must be determined by time study after careful outlining of the various operations and their most efficient sequence.

Once this program of item processing has been established, the scheduling of the necessary activities, in conformity with customer and stock order demands, can be taken care of systematically.

COST

The various control setups which have been generally outlined apply, primarily, to the purely physical and material phases of an industrial program such as output, customer supply and facility utilization, but over and above all of these we must recognize the prime importance of insuring financial security to the enterprise.

Naturally, if a concern or individual is to survive

their income must exceed their outlay, so further operational controls are essential over such things as costs, overhead pricing, etc.

Of these three, while pricing must produce profit, the element of competition between sources necessitates a backward sort of philosophy wherein cost factors must be controlled to meet market prices and less profit.

Costs consist of three general components listed as labor, material and overhead, of which the last named is a pretty complicated affair involving all stages of operations from indirect labor in a plant up to the top-executive salaries, sales, distribution and stockholders.

Since actual manufacturing costs on single items vary substantially with volume quantities, a single cost figure, representing a combination of materials, labor and overhead, that will be correct for all volumes of production and sales cannot be determined.

In view of the fact that overhead cost contains a certain amount of fixed expenses, that do not change with variations in production, the overhead cost of a single unit will be of one percentage at low production and of another when production is high, hence the total cost per unit will also change with different volumes of production.

Cost Accounting is the routine by which the material, labor and overhead elements of cost are recorded in such a manner that an analysis of these various elements can be made quickly and easily.

Cost Control is the method whereby material, labor and overhead portions of the total cost will be controlled so that actual expenses will be equal to or less than a predetermined or estimated amount.

This general procedure includes the three subsidiary routines of Material Cost Control, Labor Cost Control and Overhead Cost Control, each of which necessitates meticulous records of all items pertaining to each of the three types of expense, with constant comparative observation of the results noted in order to detect any deviations from the standards which have been set up for use in establishing pricing and budgeting.

This last item mentioned, budgeting, has to do with the over-all outcome of all company activities and, therefore, while dependent upon the intricate clerical machinery, that operates the other control activities for its own functional data, it is of prime importance to the security of the entire enterprise, including stockholders as well as management.

Simply stated, a company budget is the over-all pattern that provides proper relationship between all income and expenses of the business.

BUDGET CONTROL

As a result, budgetry control must include sales, in order to determine income, and all normal expenses, such as labor, material, supplies and overhead, as well as capital expenditures, such as development, research and new facilities, in order to keep the total outlay within the amount provided by income.

Installation of Budgetry Control involves the following major steps in the sequence noted:

1. Determination of the suitability of the following control setups
   - (*a*) Chart of accounts
   - (*b*) Distribution of labor payrolls.
   - (*c*) Analysis of the payroll for each pay period.
   - (*d*) Expense items distribution.
   - (*e*) Product and unit sales distribution.
   - (*f*) Distribution of any other income.
   - (*g*) Record of orders booked.
2. Proper charting of past expenditures on a monthly basis.
3. On the basis of Item 2, the identification of all expenses as fixed, variable, or semivariable.
4. Careful analysis of each expense to determine the possibilities and extent of economies.
5. Setting up of budget standards for each expense, expressed in terms of their fixed and variable components, and related to either sales or production, as expressed by direct labor. Any of the expected economies, as deemed possible under Item 4, should be taken into consideration.
6. Formulation of a Cash Forecast to determine if cash will be available to meet the contemplated expenditures. Such a forecast must include monthly and cumulative totals of sales, production, inventory changes, collections, receivables, payables and disbursements, together with any shift in cash before the outlay for income taxes, dividends, betterments, etc.
7. A Classification of the Budget Formula, broken down in accordance with the Profit and Loss Statement and in detail for each of these divisions.
8. A testing of the formula arrived at to determine whether sufficient profit will result from the Cash Forecast after using forecasted sales figures and meeting budget standards.
9. Compilation of a budget manual on the basis of the above-mentioned components.
10. Preparation of statement forms for the various management sections with which they can compile and present the actual results in comparison with the Budget Standards of their particular activity functions.

ORGANIZATION

Now, while the foregoing has cited the general structure of what will provide sound controls for a business or industry organization there is one vital point which must be placed at top priority if any constructive results are to be accomplished. This is the matter of actually making use of the routines which have been set up, which means, not only following all the routines provided but also seeing to it that something is done promptly if, as and when a negative variation from standards occurs. Unless this is done, no worth-while results, from an economy standpoint, can be expected.

If you hop in your car, slam the door shut and step on your starter but forget to turn on your switch, all

you to is drain the battery. In other words, even though a concern has set up a well-designed system of accounting, with proper records and routines, the actual results will be both deceptive and costly unless the initial data are correctly fed into the mechanism of the control setup.

A short time ago, the writer made a study of a tremendously big plant where several thousand workers were on the pay roll. As with most industrial organizations, the work day at this plant was scheduled as eight hours. However, a careful check of actual services showed that the real work period of all mechanics and helpers averaged only four hours per day per worker. This condition not only greatly padded the payroll but also made the costs of the many various jobs all out of line with what they should have been. Instead of the actual starting and stopping time on a certain job assignment being recorded on the particular worker's time card, the foreman merely scribbled down a figure of so many hours on the job card itself.

The above case is cited only to illustrate the necessity for accurate and systematic recording of all time spent in regard to both the people who were being paid and the costs of the individual jobs themselves. In other words, as in the case of any well-set-up layout of both operational systems and pipe lines, it is essential that a thorough and accurate report of all inflows of time, money and material be insisted upon.

Silver Alloy Brazing of Stainless Steel

by R. C. Jewell

CERTAIN data and figures have been published from time to time concerning the strength of silver-alloy brazed joints on mild steel and stainless steel.[1-4]

A perusal of these references will show considerable divergencies between the strengths of butt joints in mild and stainless steel as affected by joint clearances and thickness of brazing alloy.

Reference 3 shows that the strength of a silver-brazed joint in mild steel is independent of the joint clearance and the statement is made that this refers to any metals with which the silver-brazing material does not alloy to any appreciable extent; this statement is therefore extended to stainless steel. Moreover, it is stated that the strength of the joint is no greater than that of the brazing alloy in the cast state.

Beatson and Brooker[4] reiterate this statement for mild steel and infer its extension to stainless steel.

The strengths of butt joints in stainless steel are shown to be very markedly dependent on joint clearances by Leach[1] and later work by Coxe and Setapen[2] supports this and confirms that joint strengths obtained are much greater than that of the as-cast brazing alloy.

We have recently been examining the factors affecting the strength of butt joints made in stainless steel with silver-brazing alloys. Our first experiments revealed widely scattered results, some good, some very bad. Subsequent work is enabling us to isolate the factors and assess their relative importance. As a result of this work we have developed a technique for producing high-strength butt joints and have consistently obtained results beyond the yield point of stainless steel, not only at room temperature but at elevated temperatures up to 350° C. Tensile strengths at room temperatures up to 40 tons per square inch have been obtained so far, which is well beyond the strengths of the silver-brazing alloys used (approximately 30 tons per square inch).

Whereas the present-day technique for producing sound joints in mild steel is well known and highly satisfactory, similar satisfactory results by the same technique are not obtained on stainless steel—thus a specialized brazing technique is necessary to produce consistent strengths of brazed butt joints.

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3. Ministry of Supply, Memorandum on Brazing, Welding Memorandum No. 9.
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PRACTICAL WELDER AND DESIGNER

Cut Out the Old, Weld in the New

by L. F. Lillard

THE oxy-acetylene processes have made car and truck repairing a big business for many welding shops and a time and money saver for the individual owner or fleet maintenance department. Ripped body sections are mended by fusion welding, worn mechanical parts are rebuilt and broken parts joined together by braze welding, leaky radiators are repaired and wiring connected by soldering and bent frames straightened and rusted bolts removed by heating.

Fig. 1 The entire side of this light truck was cut away and a new side welded in place. Oxy-acetylene cutting and welding made this repair practical. After sanding, the panel will be painted

Fig. 2 On the inside, where the door frame, roof beam and new side panel come together, a brace is being welded for reinforcement. The weld at the top of the new panel is seen beneath the roof support

Fig. 3 Another view of welding the reinforcing brace is shown here. The brace is held in position by a C-clamp during welding. A cutting blowpipe shaped this brace out of 18-gage sheet steel

Fig. 4 Here is a helpful tip on removing body dents. With a cutting blowpipe, cut away the inside panel right behind the dents. Now you can pound out the dents easily, then weld the panel back in place

Cutting comes into its own on auto and truck body repair. Ripped fenders, which must be replaced, are cut off easily with an oxy-acetylene cutting blowpipe so that bolts which hold the fenders in place can be reached and removed without loss of time. Side panels, torn beyond repair are cut away and new sections cut from sheet steel, are welded into place. Reinforcing braces for weak points are shaped with a cutting blowpipe.

Cutting and welding team up to make repairs that are too big or too expensive when handled in any other way. Cars and trucks that have been badly damaged in collisions often can be salvaged by cutting away damaged sections and welding on new pieces.

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Aluminum Trailers

MINUTES count when you are girding for defense. Recently, at the the urgent request of the U. S. Air Force, one company started producing welded aluminum utility trailers four and a half times faster than they had previously, thanks to a combination of proper jigging and changeover to the relatively fast Aircomatic welding process.

Before Aircomatic, setup and welding time required for the 260 lineal inches of butt, edge and fillet welds was approximately four hours per trailer, or less than two trailers per working day. Initial tests with Aircomatic proved that setup and welding time could be pared down to approximately 21 min per trailer, a time reduction of about 90%.

The trailers were fabricated almost entirely from 61S-T6 aluminum. An Aircomatic Gun fed $^1/_{16}$-in. diam 43S aluminum wire to the joint at about 225 ipm using 180 amp of welding current with helium as the shielding gas.

The welding jig used for this job provided maximum

Fig. 1 Close-up of indexing device showing jig position nearly horizontal

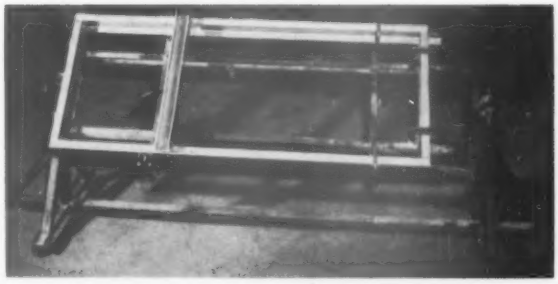


Fig. 2 Parts clamped in special jig ready for welding

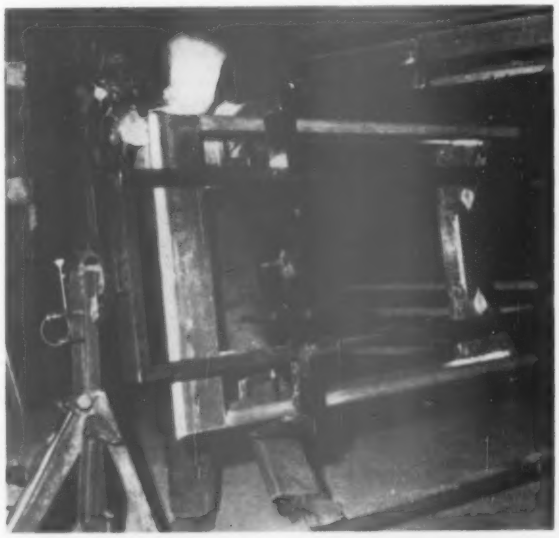


Fig. 3 Jig shown in the vertical position

Fig. 4 Completed trailer

speed with minimum effort. Fabricated almost entirely from scrap channel iron, the relatively inexpensive jig featured a unique indexing arrangement which allowed the operator to rotate the clamped trailer frame components to required positions for welding.

Figure 1 shows a close-up of the indexing device. An automobile choke control cable terminates in a pin which enters one of the holes in the drilled ring attached to the rotating frame. Pulling the choke control knob releases the pin, allowing the entire jig to be rotated to a new position. The jig employs other innovations designed to make the entire welding operation easier and faster. For instance, note the studs welded to the frame for keeping hammer and clamps within easy reach of the operator. Positioning the parts for welding is a simple operation consisting of no more than clamping the precut pieces to the jig bed, as shown in Fig. 2. In Fig. 3, the jig is shown holding the almost completed frame rigidly in a vertical position. Note how even in this position, the jig permits the operator to maintain his upright stance—an important factor when considering operator fatigue.

The completed trailer, shown in Fig. 4, is now ready for service, its all-welded frame and heavy-duty wheels ready to withstand the arduous tasks imposed upon it by the men who fly and service our airplanes.

Old Boiler Tubes Become Gate Frames

OLD boiler tubing is still serving a useful life on the Illinois Central in the form of sturdy gate frames built by the oxy-acetylene welding and cutting process.

Used $2^1/_2$ in. boiler tubing is trimmed to desired lengths, and the ends beveled to a 45-deg angle with a cutting blowpipe. Ends are butted together at right angles and welded to form corners for the gate. No jig is needed for these operations. Welding is performed with $^1/_4$-in. Oxweld No. 1 steel rod. Welded joints require no finishing in this process.

Fig. 1 Strong fusion welds are made at the corners of the frame

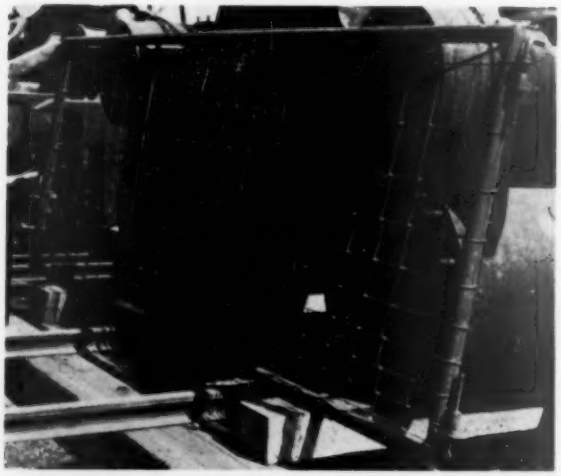


Fig. 2 Here is the finished gate frame. Six of these are made in one day

Completed gates are 53 in. high and vary in length from 16 ft or more. Ease and speed of fabrication enables a welding operator and helper to make six of these gates a day. Cost per gate, using this material and method, is about half the cost of a new gate.

Hints for Welding Sheet Steel

by Y. Hale

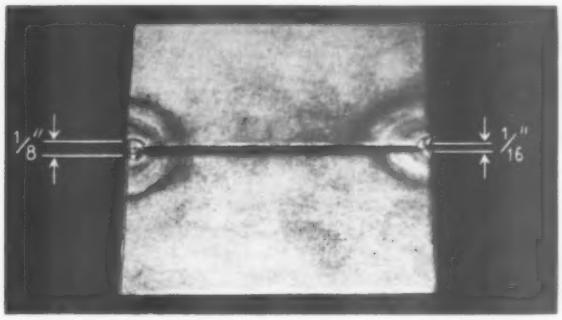


Fig. 1 After cleaning the weld area, space the sheets about 1/16 in. at the right, widening an additional 1/16 in. for every foot of seam. This allows for metal expansion and contraction and prevents overlapping. Tack weld at each end to hold sheets in position

Fig. 2 Use a neutral flame for fusion welding steel. The flame is neutral when equal volumes of oxygen and acetylene are burned. You can adjust to this easily by starting with an excess acetylene flame and then increasing the oxygen. When the excess acetylene feather has just disappeared, the flame is neutral

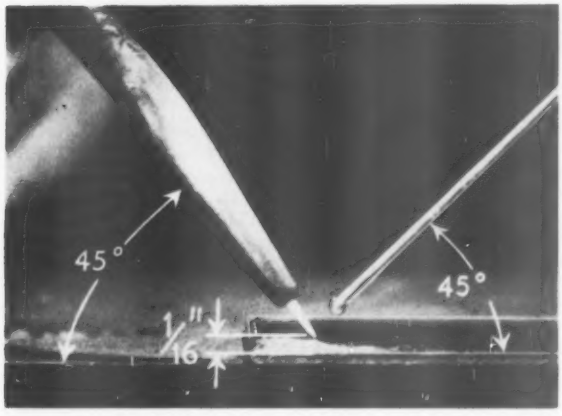


Fig. 3 Hold the rod and blowpipe at an angle of 45 deg to the workpiece throughout welding so that the flame preheats base metal in front of the puddle. The weld puddle tends to move in the direction that has been heated and requires less effort to control it

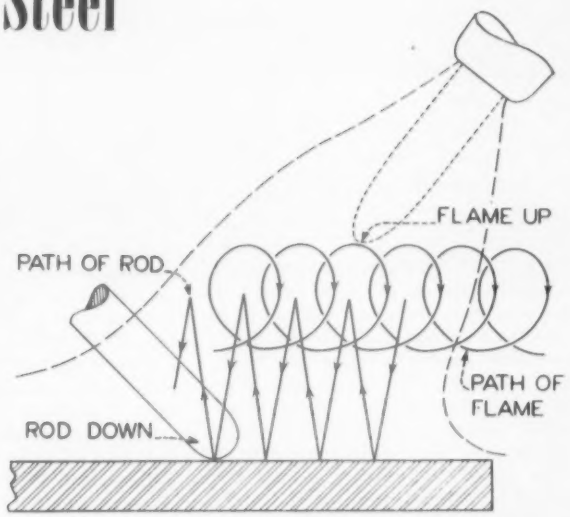


Fig. 4 Synchronize rod and blowpipe movement so that melting of rod metal does not interfere with puddle control. Feed the rod into the puddle as the flame starts upward near the front of the puddle. Lift the rod as the flame circles down near the rear of the puddle

Fig. 5 Too much heat creates holes. Too large a flame, side-to-side movement and too slow welding speed mean excess heat and too large a puddle. To correct this, withdraw the flame so that only the outer envelope touches the puddle until the weld metal hardens

Fig. 6 This is a good, sound weld. The top side is uniform in height and width and has distinctive, evenly spaced ripples across its surface. The underside would show penetration of the weld metal completely through a joint fused solidly in a continuous bond

Y. Hale, Linde Air Products Co., Kansas City, Mo.

the AMERICAN WELDING SOCIETY

activities • related events

New Sustaining Member

The R. C. Mahon Co., 6565 E. Eight Mile Road, P. O. Box 4666, Detroit 34, Mich. The engineering and production facilities of the company are devoted to the development and manufacture of a wide range of products utilized in commerce and industry throughout the world. Its Steel-Weld Division fabricates machine bases, frames and mounts, Diesel engine crank cases and cylinder housings, gun mounts, tank turrets and numerous other welded steel products and units of special equipment. Its Structural Steel Division designs, fabricates and erects buildings, bridges, locks, dams, wind tunnels, etc. There are also departments for the fabrication of industrial equipment, rolling steel doors, steel roof deck and insulated sidewall panels, as well as a complete steel warehouse division.

R. C. Mahon—Sustaining (A) Member Representative.

Southwest Welding and Allied Industry Exposition

The opportunity to attend an outstanding welding exposition and of hearing the latest in technical papers on welding engineering, procedure and metallurgy, both combined with visiting an area that is outstanding in its employment of welding for every type of structure, is meeting with widespread interest among AWS Membership and those interested in activities of the AMERICAN WELDING SOCIETY.

Seldom has it been possible for visitors attending a combined technical meeting and exposition to enjoy exposition facilities not only adjacent to the technical meetings but fully air conditioned throughout. The welding demonstrations and exhibits will be viewed in comfort. As a result many of the attendees will enjoy staying much longer, exploring and seeing the new procedures and apparatus available, than they would under ordinary circumstances.

The City

Houston and the surrounding area offers an exceptional opportunity to visitors from the standpoint of educational, industrial and entertainment interests. In 1930 Houston's population was approximately 239 thousand. Today it is over 640 thousand (metropolitan area totals 874 thousand). Within two decades from a medium size seaport Houston has grown to be the second port in the nation on the basis of a total of over 45 million shipping tons in 1951; and has ranked second for three years.

The surrounding industrial area is both expansive and dense. The banks of the Ship Channel are banked with chemical plants, refineries and every other type of industry. Houston is the South's major industrial city as well as the South's first seaport. The Ship Channel alone is a marvelous engineering feat, being man-made and winding its way 50 miles from the Gulf of Mexico. At the head of the Channel is a man-made turning basin. Its shore facilities can load simultaneously 81 large ships. Houston is located in the heart of 134 oil fields and is the headquarters of the oil industry of the world.

Those who fear that Houston is a hot tropical city may be agreeably surprised because such is not necessarily so. The summer has a mean high of 89.6°. It does range upward to 96. Those who are coming to Houston should wear light clothes and the ladies should consider a wardrobe of cottons. It should not be forgotten that Houston has more tons of air conditioning throughout its various public buildings, hotels, restaurants, museums—and even homes—than any city in America. Therefore, almost everywhere that the visitor will wish to go in Houston in June, he or she will find comfort.

Educationally Houston ranks high, being the location of the Rice Institute founded in 1912—a coeducational Institute. This 30 million dollar Institute is located on a 300-acre campus. In addition the University of Houston, a Texas youngster, has in the past eighteen years grown to the point where it has the second largest enrollment of any college or university in Texas. There is the recently new (four-year old) university of St. Thomas and the unique Texas State University for Negroes.

The new Texas Medical Center is one of the show places of Houston. It is now under construction on 161 acres and has been in development for the past six years. Upon completion the project will contain more than one dozen modern hospitals, several large nurses' homes, a medical laboratory, dormitories, apartments, research laboratories and numerous other buildings. Its official cost will be well over 100 million dollars.

Entertainment

For those who are thinking of local or near-by entertainment, the area abounds with opportunity. Galveston Bay is only a 25-mile drive from Houston, and the resort of Galveston City a mere 1 hour's drive along one of Texas' most modern superhighways. Galveston Beach is world famed. Visitors can enjoy fishing, swimming, boating and sightseeing, as well as the shore promenade and the piers. In and about Houston there are other interesting historical and entertainment facilities. A short 22-mile drive from Houston brings the visitor to the San Jacinto State Park where the San Jacinto Monument (taller than the Washington Monument) is located. At its base is found a very interesting museum which specializes in Texas history and relics. Nearby is the San Jacinto Battleground, a battle which resulted in the birth of the Republic of Texas, and which was won under the famed General Sam Houston who later became President of the Republic of Texas and, later, Governor of the State of Texas. Nearby is the battleship *Texas* in permanent berth. It has been made into a shrine, having been presented to the State by the U. S. Navy in 1948.

Other interesting entertainment features are the concerts conducted by the Houston Symphony Orchestra in the Miller Memorial Theater in Hermann Park, the Museum of Fine Arts and the wooded Memorial Park on the banks of Buffalo Bayou. The golf enthusiast will find many opportunities to exercise his hobby in not only the public parks but also the many clubs. If he wants practice only, there is always a spot alongside the Shamrock where he may do so.

In addition to many novel features of interest to the ladies there are outstanding fashion shows held in the Shamrock Hotel and in the Sky Terrace Restaurant of the Sakowitz Store, within a short walk, are many fine cafes serving every possible variety of food. And for those who would like to bring their families and drive to Houston, as the room reservations sent out some time ago stated, there are ex-

cellent Motel facilities in the area. Many of these Motels are equipped with swimming pools, playgrounds and even television.

Vacation Combination

The National Railways of Mexico offer an excellent opportunity to Houston visitors to make a planned tour of Mexico City. This tour will leave Houston at 7:50 A.M., Saturday, June 20th, and cross the International Bridge over the Rio Grande into Mexico at Laredo; then ascend the Central Mesa 5000 ft above sea level. Stops will be made at San Luis Potosi, Queretaro, and other interesting cities, arriving in Mexico City at 8:00 P.M. and transferring in private automobiles to a modern hotel, on Sunday June 21st. Monday: Tours of Mexico City's residential sections, colorful flower park and business district area. Tuesday: Visit the Shrine of Guadalupe, the Pyramids of the Sun and Moon at San Juan, Teotihuacan, and to the Acolman monastery. Wednesday: To the floating gardens of Xochimilco and then to Cortes' palace. Thursday: To the old mining town of Tasco. Friday: Over the mountains and plains to Puebla and a visit to Cholula ancient site of the Toltec Dynasty, with views of several volcanoes. Leave Saturday June 27th, arrive in San Antonio at 1:30 P.M. Sunday. Details can be secured through F. Alatorre, General Agent of the National Railways of Mexico, 2401 Transit Tower, San Antonio 5, Tex. A smallpox vaccination certificate must be available as issued within the last three years for U. S. Health authorities. Here is an excellent opportunity to see old Mexico.

The Exposition

Of course the most important activities of all will be the dual presentation of the Exposition and the Technical Program. At this writing more than sixty national organizations have contracted for space. There is no adequate way to describe an Exposition. It has to be seen. It will be outstanding and it will be worth while seeing. The Exposition will open at noon on Tuesday, June 16th. The exposition hours will be as follows: Tuesday and Wednesday 12:00 noon to 10:00 P.M.; Thursday and Friday 10:00 A.M. to 6:00 P.M.

Technical Program

Starting on Tuesday morning at about 10:00 A.M. the Society will present a series of Technical Sessions each containing outstanding technical papers. A complete tentative program will be found in this issus of The Welding Journal.

Tentative Technical Program
AWS National Spring Meeting
Houston, Texas
June 16–19, 1953

TUESDAY MORNING, JUNE 16th

Two Simultaneous Sessions

1—WELDING TITANIUM

Effect of Atmospheric Contaminants on Arc Welds in Titanium
by J. C. BARRETT and I. R. LANE, JR., U. S. Bureau of Mines

The Effects of Iron, Manganese, Chromium and Molybdenum on Welds in Titanium
by G. B. GRABLE, C. B. VOLDRICH and G. E. FAULKNER, Battelle Memorial Institute

Brazing of Titanium
by J. M. PARKS and N. A. DECECCO, Armour Research Foundation

2—HUMAN ELEMENT IN WELDING

Human Elements and Problems in Welding
by DAVID P. O'CONNOR, Department of Water and Power, City of Los Angeles

Human Element in Welding
by R. C. WILEY, California State Polytechnic College

TUESDAY AFTERNOON, JUNE 16th

Two Simultaneous Sessions

3—WELDING TITANIUM

Brazing or Soldering Titanium Without Flux
by HARLAN L. MEREDITH, North American Aviation Co.

Restoration of Ductility in Alloy Titanium Welds
by ALLAN J. ROSENBERG, E. HUTCHINSON and S. WEISS, General Electric Co.

Spot Welding of Titanium—Carbon Alloys
by E. F. HOLT, P. R. MALLORY and Co., Inc., F. H. VANDENBURGH, Mallory-Sharon Titanium Corp., and N. L. McCLYMONDS, P. R. Mallory & Co. Inc.

4—RESISTANCE WELDING

Flash and Pressure Weld Qualification Tests on 4340 Steel Heat Treated to 260-280,000 Psi After Welding
by MARIO L. OCHIEANO, Lockheed Aircraft Corp.

Basis for a Resistance Welding Specification for the Electronic Industry
by PETER G. POETTO, CBC Welding Corp., STEPHEN A. MONTANARO and HAROLD SHARNEY, City Testing and Research Laboratory

There will be a special activity of overall interest on Thursday afternoon merging into an activity of entertainment interest for Thursday evening. Its nature will be announced later.

Interesting industrial plant tours are being arranged. Should a visitor wish to make special arrangements to visit several industrial plants rather than in organized groups, it is suggested that he communicate in advance with such organizations for making the required arrangements.

We know there will be keen interest in the unusual recreation features and activities provided at the Shamrock. Many ladies have expressed interest in the Shamrock kitchens, which are unique, with very modern facilities for large-scale handling of food. For their interest, a tour of the Shamrock kitchens shall be arranged at a convenient time.

Meeting session hours have been arranged so that there will be ample opportunity for everyone attending to both engage in the technical activities of the SOCIETY and to visit all exhibits in the Exposition Hall.

We are looking forward to seeing you in Houston.

WEDNESDAY MORNING, JUNE 17th

Three Simultaneous Sessions

5—RESISTANCE WELDING SYMPOSIUM

(Arranged by Technical Activities Committee)

I Instrumentation

II Techniques and Welding Schedules
(Continued in Afternoon)

6—INERT ARC WELDING

Inert Arc Welding Without a Backing Strip
by H. S. BLUMBERG, M. W. Kellogg Co.

Heliarc Welding of Stainless Steel Piping
by F. J. PILIA, Linde Air Products Co.

7—ALUMINUM

Recrystallization Welding
by JOHN M. PARKS, Armour Research Foundation

Joining Aluminum to Other Metals
by MIKE A. MILLER, Aluminum Research Laboratories

Some Consideration on Weldability of Aluminum Alloys
by J. KOZIARSKI, Piasecki Helicopter Corp.

WEDNESDAY AFTERNOON, JUNE 17th

Three Simultaneous Sessions

8—RESISTANCE WELDING SYMPOSIUM

(Arranged by Technical Activities Committee)

III Production Quality Control

IV Applications

A Stainless Steel Aircraft

B Aluminum Aircraft

9—STRUCTURAL WELDING

Welded Rigid Connections for Portal Frames
by A. A. TOPRAC, University of Texas

An Evaluation of Plastic Analysis as Applied to Structural Design
by B. G. JOHNSTON, University of Michigan, C. H. YANG and L. S. BEEDLE, Lehigh University

Plastic Strength and Deflection of Continuous Beams
by K. E. KNUDSEN, C. H. YANG, and L. S. BEEDLE, Lehigh University, and B. G. JOHNSTON, University of Michigan

Applications of Plastic Theory
by W. S. ATKINS, College of Technology, Liverpool

10—INERT-ARC WELDING

Inert-Arc Welding by the Fillerarc Process
by R. W. TUTHILL, General Electric Co.

Stranded Electrode Materials for Aircomatic Welding
by H. ROBINSON, Kaiser Aluminum and Chemical Sales Co., and H. C. COOK, Air Reduction Laboratory

Fusion Welding of Light-Gauge Alloys
by JACK T. MALONEY, Rohr Aircraft Corp.

THURSDAY MORNING, JUNE 18th

Two Simultaneous Sessions

11—STORAGE TANKS AND PIPE LINES

Automatic Field Welding of Girth Seams of Large Storage Tanks
by PERRY C. ARNOLD, Chicago Bridge and Iron Co.

Impact Strength of Arc Welds at Low Temperatures
by J. R. WATT and J. J. SMETANA, University of Texas

The Use of Magnaflux for Quality Control of Pipe Line Welds
by GEORGE L. C. DEHN, Magnaflux Corp.

12—STAINLESS AND ALLOY STEELS

Stabilizing Austenitic Chrome-Nickel Weld Metal Against Intergranular Corrosion
by H. C. CAMPBELL, Arcos Corp.

Submerged-Arc Welded Vessel Linings
by JAMES G. KERR, C. F. Braun & Co.

Applications of Medium Alloy, High-Strength Steel in Welded Construction
by HOWARD L. MILLER, Republic Steel Corp., and ARTHUR E. WILKOFF, Youngstown Steel Car Co.

FRIDAY MORNING, JUNE 19th

Two Simultaneous Sessions

13—ARC WELDING APPLICATIONS

Arc Welding of Ferritic and Austenitic Nodular Cast Iron
by HARRY FISK, JESSE S. SOHN and WILLARD M. BOAM, Wright Aeronautical Div., Curtiss Wright Corp.

Fusion Welding of Ductile Iron
by T. E. KIHLGREN and H. C. WAUGH, International Nickel Co., Inc.

Maintenance Welding in the Petroleum Industry
by DON H. RASMUSSEN, Eutectic Welding Alloys Corp.

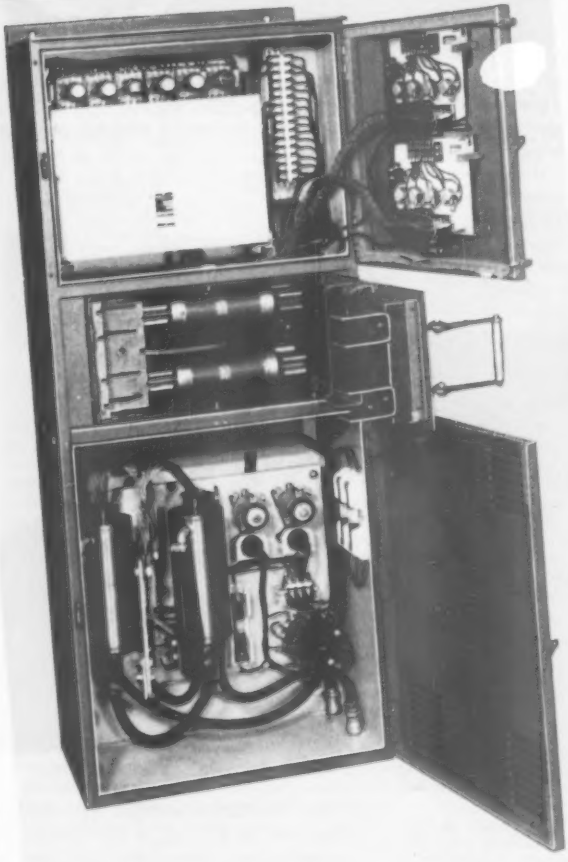
14—MARINE STRUCTURES

Tricky Problems in Welded Ship Repair
by MILTON FORMAN, Todd Shipyards Corp.

Residual Stresses in Welds
by BELA RONAY, U. S. Naval Engineering Experiment Station

faster!

WELDING PRODUCTION ON REPEAT OPERATIONS



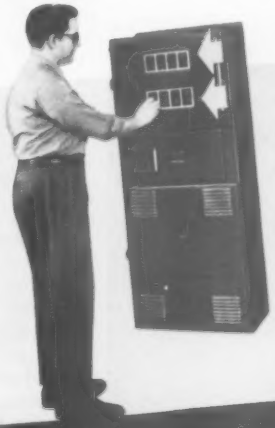
Square D's *High-Speed* Electronic Welder Control

faster! More spot welds per minute for repeat gun or machine welding operations . . . obtained by providing an additional SQUEEZE DELAY timing and a negative HOLD time sequence.

more consistent welds! Synchronized firing of ignitron tubes (welder transformer) and full cycle conduction provides uniform heat for each weld. Vastly improves quality of work.

less maintenance! Control unit uses heavy duty relays and components specifically designed for high speed welding service. Minimizes down time.

plus safety! Positive weld termination prevents danger to the operator and damage to machinery. Square D Fail-Safe tube circuits require no conduction of additional electronic tube to stop the weld.



dual **SEQUENCE ADJUSTMENTS** . . . provide complete control of two welding guns operated from one welder transformer and controller.

Write for High Speed Welder Control Bulletin #8992. Square D Company, 4041 North Richards Street, Milwaukee 12, Wisconsin.

SQUARE D COMPANY

1903 · 50 YEARS OF DESIGN LEADERSHIP · 1953

PERSONNEL

A. F. Davis Honored

The new 200-bed Glenville Hospital in Cleveland, Ohio, noteworthy because of its all-welded steel frame and unique square floor plan which permits service to any patient in a matter of seconds, has announced the election of A. F. Davis as President of the Board of Trustees. Davis is Vice-President and Secretary of The Lincoln Electric Co. He has been a member of the Hospital Board for eight years and was Chairman of the Finance Committee which raised approximately $4,000,000 to build the hospital. Besides servicing the community of Euclid, Ohio, Glenville Hospital also is in an area containing many of Cleveland's well-known companies: Thompson Products, Fisher Body, Weatherhead Co., National Acme Co., Willard Battery, The Lincoln Electric Co., Chase Brass & Copper, Addressograph-Multigraph, Euclid Road Machinery and others.

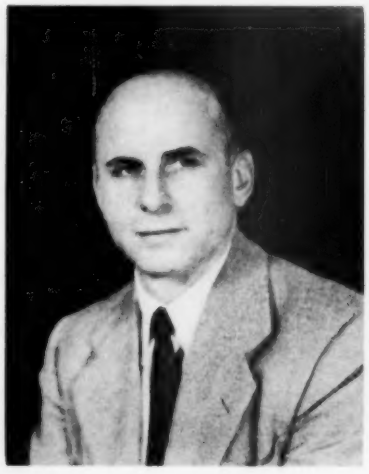
Ralph Gross Joins Southern Oxygen Co.

Ralph Gross has been appointed to the Southern Oxygen Co. as sales service representative. In this position, Mr. Gross has been assigned to the equipment and supply division out of the Philadelphia district office of the company to service a section of Southeastern Pennsylvania and Northern Delaware.

Mr. Gross was formerly associated with the New York Shipbuilding Corp. in the Welding Engineering Department where he held a position as Junior Engineer. Prior to his employment with New York Ship, Mr. Gross was associated with the Philadelphia Board of Education as an Instructor in the welder training program. He is a graduate of Philadelphia Central High School. He completed a welding engineering course at Drexel Evening Technical College, and a physical metallurgy course at Temple University. Mr. Gross is an active member of the AMERICAN WELDING SOCIETY.

Marzke Made Consultant

Oscar Theodore Marzke, superintendent of the Metallurgy Division at the Naval Research Laboratory, has been named consultant to the director of research at NRL in the fields of chemistry, electricity, mechanics and metallurgy, it was announced recently. Dr. Marzke, who resides at 3227 N. George Mason Dr., Alexandria, Va., is also head of the Metallurgy Branch of the Office of Naval Research. He will retain both positions while serving in his new capacity.



A native of Lansing, Mich., Dr. Marzke received his undergraduate education at Michigan State College and obtained his Doctor of Science degree from the Massachusetts Institute of Technology. During part of the time he was taking his graduate work, Dr. Marzke served as a laboratory technician at the Naval Research Laboratory. From 1933 to 1946, he was a metallurgist with the American Steel & Wire Co., becoming works metallurgist at the Waukegan, Ill., plant in 1942. He joined the Laboratory in 1946 as superintendent of the Metallurgy Division.

Dr. Marzke is a member of the American Society for Metals, the American Institute of Mining and Metallurgical Engineers, the AMERICAN WELDING SOCIETY, Tau Beta Pi, the British Institute of Metals and the British Iron and Steel Institute. He is the author of several papers in the field of metallurgy, his chief scientific interest being in the relation between structure and behavior of metals.

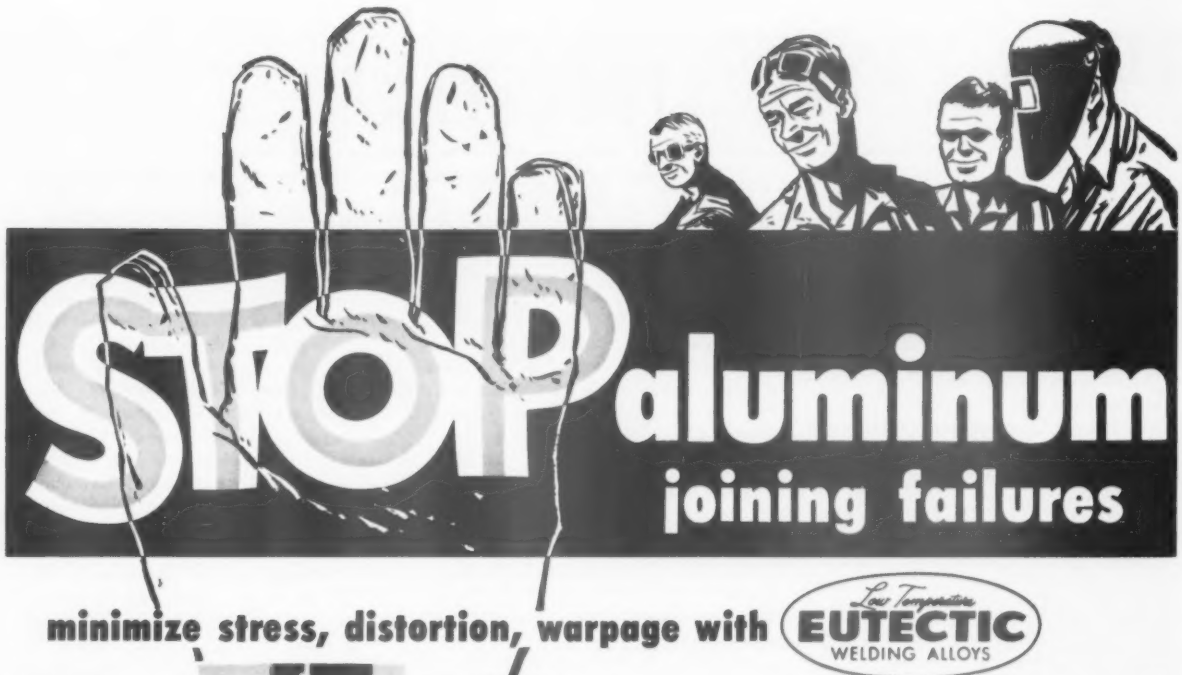
C. C. Zimmerman Named Executive Vice-President

Charles C. Zimmerman, vice-president and chief engineer of the Benjamin F. Shaw Co., Wilmington, Del., was named executive vice-president at the meeting of the board of directors on January 19th.

Mr. Zimmerman, who has been with the Shaw firm for 20 years, is chairman of the executive committee of the Pipe Fabrication Institute. He is a member of the American Society of Mechanical Engineers and the AMERICAN WELDING SOCIETY.

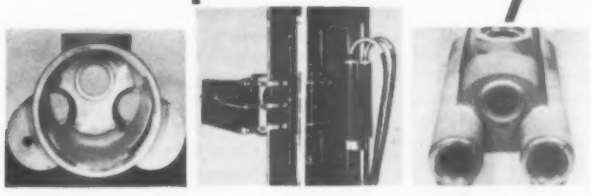
The official is also a past-president of the Allied Construction Industries of Wilmington and chairman of the Master Plumbers Assn. and the Associated General Contractors.

The Benjamin F. Shaw Co., known since 1893 for high-quality piping, prefabrication and installation, is celebrating its 60th anniversary this year. The company is qualified to prefabricate and erect piping throughout the world.



STOP aluminum joining failures

minimize stress, distortion, warpage with Low Temperature EUTECTIC WELDING ALLOYS



Previously Considered "Impossible", 11-Part Liquid-Proof, Shock-Proof X-Ray Assembly Now Welded for Maximum Strength, Safety

"Our X-Ray tube housing is fabricated from eleven different parts that are assembled and welded. This assembly is then immersed in water and tested to withstand 50 lbs., air pressure to insure against leaks or porous welds. After the tube is joined, the inside of the housing is lined with lead to imprison the dangerous X-Rays.

An additional factor that makes this such a difficult metal-joining problem is the extremely wide temperature range to which the housing is subjected. The tube, ordinarily remaining at room temperature when not in use, rapidly attains a heat of 215°F. in operation, making the use of solder impractical.

Test after test of welding alloys in various price ranges had failed in one or another of the requirements. One of the chief causes of failure was the high heat at which conventional welding alloys are applied. This high heat either melted the delicate threading on the fittings or required extensive aftermachining and finishing before the crinkle finish could be applied to the completed piece.

Finally EutecRod 190, the new EUTECTIC Low Temperature WELDING ALLOY, was recommended and tested — and met *all* requirements! Expensive finishing was eliminated due to the unique thin-flowing characteristics of the alloys. Because of the low heat of application, the threads remained unharmed, rejects were eliminated, and production speed increased enormously. Tensile tests definitely proved that the strength of the joint was multiplied many times over—while the actual cost per job decreased!

The day we first tested EutecRod 190 was an extremely profitable one for us!"

*—M-Laboratories, Connecticut**

*Full name and address on request.

Impossible? That's what the "M-Laboratories" thought, too, until they actually tried these new entirely different EUTECTIC Low Temperature. WELDING ALLOYS.® Then they came up with the astounding "Case History" shown on the left.

Yes, we not only *claim* this amazing performance — we *prove* that "EUTECTIC" is different . . . *prove* that these new alloys solve metal-joining problems where conventional materials fail!

Let us prove it in YOUR shop, just as we have in over 78,000 other plants and shops throughout America. There's no cost, no obligation involved. Just fill in and mail the coupon, below, for a FREE Consultation-Demonstration from one of our 350 trained District Engineers who stand ready to serve you from coast to coast. **Prove to yourself that there is something new and different in metal-joining . . .**

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"Manual of Welding Design and Engineering" with 50 new photos, 60 new drawings. Send for YOUR free copy TODAY.

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NEW LITERATURE

Arc Welding

A new 40-page book showing how arc welding pays is being mailed free of charge by Hobart Brothers Co., Troy, Ohio.

There are over 100 photos pointing out how arc welding is used profitably in 18 different industries for production, maintenance and repair. Some of the industries covered are: automotive, construction, heating, machinery, petroleum, farming, railroad and shipbuilding.

Subsequent pages show line of Hobart arc welders, electrodes, accessories, and describes features of Hobart welders. For your free copy, write Hobart Brothers Co., Troy, Ohio.

ASME Unfired Pressure Vessel Code

Section VIII of the 1952 ASME Boiler and Pressure Vessel Code covers the design, construction, inspection and tests of unfired pressure vessels of carbon and low-alloy steels, nonferrous materials, high-alloy steel, materials, fabricated by welding, riveting, integral forging and brazing. It includes recommendations for pressure-relieving devices, stamping and recording.

Two mandatory appendices give design formulas, rules for bolted flanged connections and definitions. Sixteen nonmandatory appendices provide suggestions for using new material; a method for obtaining operating temperature of vessel walls in service; practices regarding internal structures, corrosion allowance, linings, design of supports; and for inspection, repair and allowable working pressures for vessels in service; installation and operation suggestions, examples illustrating the application of code formulas and rules, basis for establishing stress values for ferrous and nonferrous materials, steel casting requirements for high quality factor, capacity conversions for safety valves, direction for sectioning of welded joints, and the facing dimensions for steel-pipe flanges and flanged fittings.

As the rules in the 1952 Code cover the use of all classes of materials and methods of fabrication that have been approved for Code construction, they are to be used without supplement from earlier editions or from code cases applicable only to earlier editions.

Copies may be obtained from The American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y., at $3.50 each.

Hardness Conversion Tables for Steels

A celluloid card, wallet size, gives approximate relationship between Brinell, DPH (Vickers), Rockwell and Shore Scleroscope hardness values and corresponding tensile strengths of steels. Data from *SAE Handbook*. International Nickel, New York 5, N. Y.

Mechanics of Materials

By Seibert Fairman and Chester S. Cutshall. In these pages Professors Seibert Fairman and Chester S. Cutshall attempt to make this subject meaningful to students by showing them how to apply the theory to practical situations. They provide a sound understanding of the elements of mechanics of materials and a thorough training in the use of basic principles, while keeping the material at the level of the average engineering student.

The book contains six outstanding features:

1. Numerous illustrative examples, completely solved, to aid the student in learning how to apply the principles.

2. A more thorough explanation and illustration of the application of the area-moment method in connection with both statically determinate and statically indeterminate beams than is found in most other books.

3. A more thorough and systematic treatment of combined stresses than is offered in most books.

4. A treatment of columns designed to give the student a better understanding of the basic theory and its connection to the development of the empirical formulas used in practical design.

5. A large selection of problems to be solved by the student, over 700. Some of these problems are grouped at the ends of the specific articles on which they are based; the others are grouped at the ends of chapters and are often more general in nature or of a higher order of difficulty.

6. Elimination of certain advanced topics, included in many elementary books, which are primarily applications to some special field and are usually treated to better advantage in subsequent design courses —for example, structural connections, riveting of plate girders, shear flow, etc.

Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 1946, 267 pp., 422 illustrations, 6 by 9¼. Price $5.75.

Slag-Metal Interaction in Arc Welding

The Welding Research Council has just issued *Bulletin No. 15* of its regular Bulletin Series on the above subject. This is a report prepared by Nils Christensen, formerly Assistant Professor of Metallurgy, Massachusetts Institute of Technology, and now with the Norwegian Institute of Technology, and John Chipman, Head of the Department of Metallurgy, Massachusetts Institute of Technology.

The Bulletin consists of 14 pages, 9 x 12 size, and covers a study of the interaction between slag and weld metal under varied conditions of arc length, current, welding speeds, type of electrodes and base metal. The study of slags rather than of the charged materials has been fruitful in the field of steelmaking. Corresponding relationships between welding slags and weld metal may be expected. But they have to be established by experiment, for the temperature-time cycle in arc welding is quite different from the conditions prevailing in a steel furnace. Information on the interaction between slag and weld metal is important for a better understanding of the arc-welding process as well as for practical applications in electrode design. Such knowledge is essential also for a rational metallurgical classification of welding electrodes.

This Bulletin may be purchased from the American Welding Society, 33 W. 39th St., New York 18, N. Y. Price $1.00 per copy.

Guidebook on Maintenance of Clad Steel

An illustrated guidebook, *Cleaning and Maintenance of Clad Steel Equipment*, has recently been published by Lukens Steel Co., Coatesville, Pa. Lukens early developer of clad steels, produces such well-known lines as stainless-clad, nickel-clad, Inconel-clad, Monel-clad and copper-clad.

Pointing out the small amount of maintenance and low-cost cleaning necessary for stainless and nickel alloy equipment, the guidebook outlines for maintenance personnel recommended cleaning procedures for those types of surface contamination which are potentially harmful. It contains solution formulas for cleaning specific kinds of surfaces, and includes information on handling clad steel equipment during relocations.

Users of clad steel equipment may obtain copies of this guidebook from fabricators who supply equipment of these materials.

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MAGNA-WELD LENS

REGAINS LOST BIFOCAL VISION

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WITH MAGNA-WELD LENS
Bifocal power is provided through entire window area, completely eliminating use of eyeglass bifocal segment.

Now...an effective optical aid which gives the welder who wears bifocal glasses the advantage of "full window" vision.

The Magna-Weld has lenses made of fine ophthalmic glass, precision ground and polished, and mounted in a sturdy frame which fits any standard welding helmet.

Magna-Weld comes in 2 sizes, 2"x4 1/8" and 2"x4 1/4" and in 8 accurate powers — 0.75, 1.00, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50.

Penoptic's manufacturer-to-you distribution policy offers new opportunity to save with safety. For price and full information, write directly to the Pennsylvania Optical Company, Reading, Pa.

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When you want
high impact strength
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When these shovel jaws swing open, tons of rock and earth pound every welded joint of this truck body. Only weld metal of the highest impact strength can absorb the punishment.

You can depend on Arcos Low Hydrogen Electrodes for *all* of your high tensile welding applications—not just jobs like this that require maximum ductility and impact strength. The rigid Arcos quality controls assure you weld metal of consistently superior physicals. The wide selection of Arcos grades enables you to pick the right electrode for every job. Send today for your free copy of "The ABC's of Welding High Tensile Steels". Arcos Corporation, 1500 South 50th Street, Philadelphia 43, Pennsylvania

ARCOS GRADE	A. W. S. SPEC.
Tensilend 70	E7016
Tensilend 100	E10016
Tensilend 120	E12015
Manganend 1M	E9015
Manganend 2M	E10015
Nickend 2	E8015
Chromend 1M	E8015
Chromend 2M	E9015

WELD WITH ARCOS
LOW HYDROGEN ELECTRODES

Automotive Repair Welding Manual

Designed primarily as an aid to economical salvage of all truck and car equipment is a brand new manual, *Truck and Car Fleet Maintenance and Repair Welding Manual*, offered free of charge by the Eutectic Welding Alloys Corp., Flushing, N. Y. This fifth in the series of "How to Weld It Better" manuals is a one-volume storehouse of new welding repair and salvage methods that can be used profitably by large and small shops alike.

Over 86 step-by-step photographs, plus 25 diagrams and charts in this 56-page book illustrate quick, simple money-saving ways to add years of service life to any automotive vehicle. Contents include repair of all stationary and operative parts grouped under these major chapter headings: Salvaging Truck and Automotive Castings; Repairing Functional and Mechanical Parts; Saving Cracked and Damaged Body Parts; Salvaging Ornaments, Accessories and Auxiliary Equipment. The clear, concise text and sharp photographs of most applications are printed on the same pages for immediate identification; a quick reference index pinpoints repair of any required part.

Industrial Brazing

Industrial Brazing by H. R. Brooker and E. V. Beatson, B.Sc. (Eng.), AMIEE. Published on Feb. 16, 1953, for "Welding and Metal Fabrication" by Iliffe & Sons Ltd., and handled through British Book Centre, 122 E. 55th St., New York 22, N. Y. Price $7.50. Size D8vo. 344 pp. 203 diagrams and photographs and 32 tables.

This important book is a full-length, authoritative study of brazing as a process for metal fabrication. The need for such a book has been evident from the rapid growth in the use of brazing as well as from the numerous requests for information on this subject from many manufacturing organizations.

The present work covers in considerable detail all modern brazing methods: torch, furnace, H.F. induction, resistance, salt bath and dip, while the special considerations necessary in work on aluminium, stainless steels, beryllium copper, cemented carbides and vacuum tube construction are dealt with separately. In addition, a general introduction to the processes and the equipment employed is followed by a review of brazing materials and the most complete summation of the known factors governing joint design. Finally, a chapter discusses problems of selecting the most appropriate brazing process for various types of work and makes a useful contribution on methods of inspection and testing.

Industrial Brazing will prove of equal

value to those engaged in industries operating brazing processes and to those who are responsible for the design of brazed assemblies. H. R. Brooker, who is Assistant Manager in the Industrial Division of Johnson, Mathey & Co. Ltd., has had wide experience in the development of brazing materials and methods, while E. V. Beatson, a welding development engineer with Joseph Lucas (Industries) Ltd., has long been intimately concerned in the use of brazing as a mass production tool.

The book is illustrated with over 200 photographs and diagrams depicting various phases of the different processes, and a vast amount of reference material is provided both in the text and in the 32 tables.

Hobart Arc Welding News

Volume IX, No. 5, "Hobart Arc Welding News," a 20-page booklet of interesting photographs and articles on welding from all over North America, is now available. Copies are mailed free of charge to anyone interested in arc welding.

Many of the articles feature time- and money-saving applications. To get your copy, write the Hobart Brothers Co., Troy, Ohio.

Arc-Welding Accessories Booklet

Arc-welding accessories are described in a 12-page booklet available from the Westinghouse Electric Corp. This line of products varies from electrode holders and ground clamps to protective clothing and headgear.

All accessories are illustrated and in every case specification data are supplied. Where several models of the same accessory are shown, the special application characteristics of each are discussed.

For a copy of this booklet, B-5451, write Westinghouse Electric Corp., Box 2099, Pittsburgh 30, Pa.

Notch Bar Testing and Its Relation to Welded Construction

This book is an authoritative survey of the present state of knowledge on a pressing engineering problem—the efficacy of different kinds of notch-bar test as a guide to the service performance of steel and especially its liability to brittle fracture.

The contributors are acknowledged experts in this field, and their contributions embody the results of recent investigations in this and several other countries. Size, 11 x 8½ in.; 80 pp.; 101 illustrations; paper boards. Price $3.75, postage free.

Obtainable from the Publishers—The Institute of Welding, 2, Buckingham Palace Gardens, London, S.W. 1.

How to get
top weld strength
at elevated temperatures

You'll certainly agree there's no room for error in fabricating the engines of today's high flying jets. Every welded part must be of top strength and offer maximum resistance to extreme heat.

Arcos Stainless Electrodes, which provide this peak performance in fabrication of jet engines, can give you the same high performance on *all* your welding applications. Use ARCOS STAINLESS ELECTRODES! They are your assurance that physically, chemically, and metallurgically you can get sound, dependable weld metal on every job. That saves worry and troubles later. And Arcos Quality Controls—most rigid in the industry—guarantee a better investment of your welding time and dollars. Write today for your free copy of "Electrode Selection for Welding Stainless and Alloy Steels". Arcos Corporation, 1500 South 50th Street, Philadelphia 43, Pennsylvania

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FULLY INSULATED MODELS

500 AMP

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OTHER MODELS ON REQUEST

FEATURES:

- CADWELD connection—cable to jaw is a 100% conductivity solid copper connection. It is permanent—cannot melt out, burn out, loosen or corrode.
- Short completely replaceable beryllium copper jaw has 80% conductivity.
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Welding Guides

Welding Equipment & Supply Co., 223 Leib St., Detroit 7, Mich., have two new welding manuals ready for distribution, namely: (*A*) *Eureka Tool and Die, or Maintenance Welding in The Forge Shop*, and (*B*) *Eureka Tool and Die Welding Guide*.

The "*A*" manual covers specialized welding in the forging industry, and the "*B*" manual is devoted to the entire tool and die welding field. They illustrate various applications of the metallic arc, atomic hydrogen and atomic arc phases of welding.

Composition of Industrial Metals

An unusual metals chart, showing the compositions of all commonly used metals and alloys in industry, has been prepared by Sam Tour & Co., Inc., a New York City firm of research and testing consultants. The chart lists the constituent elements and the percentage composition ranges for 60 different classes or types of metals arranged in the following groupings: light metals, irons, steels, cobalts, nickels, coppers white metals, precious metals, heavy metals and special-purpose metals. Also shown is the atomic number and specific gravity of each of the 48 elements commonly encountered in industrial metals. It is believed that this is the first time that this type of data has been compiled into a single, compact form.

Approximate dimensions of the chart are 16 by 34 in. A two-page explanation accompanies the chart, describing the purpose of the chart and giving useful definitions of various types of metals. Copies of the chart may be obtained upon request to Sam Tour & Co., Inc., 44 Trinity Place, New York 6, N. Y.

Resistance Welding Catalog

The new Ampco-Weld Resistance Welding catalog, *Bull. RW-1a* has just been released by Ampco Metal Inc. Milwaukee Wis.

Included in this 24-page catalog are the newly designed tips and holders which have recently been added to the Ampco-Weld line. Full information is given about the complete line of holders, tips, seam welder wheels, seam welder shafts and bushings and flash, butt, barrel and projection welding dies. Reference tables and comparative charts giving physical properties applications and RWMA specification data are also included.

A free copy is yours by writing Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis.

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quickly adjustable but entirely tamper proof

Only an Allen wrench of proper size will adjust the pressure setting of these "*self-reseating*" relief valves. They are tamper proof and cannot be made inoperative by unauthorized and inexperienced individuals.

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a safety valve which can be tampered with is very dangerous indeed . . .

a 40-page book — free of charge — offers you a wealth of regulator data; why not write for it TODAY.

Made by National SINCE 1910 WELDING EQUIPMENT CO., San Francisco 5, California

523

NEW PRODUCTS

General-Purpose Electrode

A new general-purpose mild-steel welding electrode, designed for optimum flexibility of application with reduced operator effort, has been announced by the General Electric Co.'s Welding Department.

Designated as G-E Type W-610-A, the new electrode is a d-c reverse-polarity rod meeting AWS Class E-6010 specifications.

According to G-E engineers, the electrode facilitates butt, fillet, lap joint and edge welding in all positions. Its ability to take high currents, together with freedom from reaction pitting, fingernailing, spatter and blistering of the coating, assures a high ratio of inches-of-welding to inches-of-electrode used, the engineers said.

Typical applications include the welding of pipe lines, steamlines, ship structural frames, bridges and all types of unclad pressure vessels and storage tanks.

The new electrode is available at all G E welding distributors.

Electrode

Metal and Thermit Corp. announces a new and improved grade E-6010 electrode. The new Murex Type R electrode has been tried with good results and excellent acceptance on such applications as: power piping, barge and tug boat construction, general fabrication of tanks and cylinders of various plate thicknesses, oil pipe lines, general shop welding and repair work. Those who have used it commented favorably on: small amount of spatter, uniformity of arc behavior, lack of spearing, ability to take high currents without coating breakdown or change of performance as electrode is consumed, penetration without undercutting and lack of reaction pitting when using whip technique.

These new electrodes are available from Metal and Thermit district sales offices and approximately 250 distributors who handle the Murex line. Descriptive literature may be obtained by writing to the company at 100 E. 42nd St., New York 17, N. Y.

Penetration Electrode

The Weldbest Deepweld is a new mild steel electrode of the highest penetration power, especially designed for butt and fillet welds in the horizontal position, to be used on steels from 54,000 to 80,000 psi tensile strength.

Economy of welding can be achieved with this electrode by elimination of joint preparation of plates up to $^{3}/_{4}$ in. thick. Square butt joints suffice.

Due to its deep penetrating characteristics, the Weldbest Deepweld electrode fuses more base metal than standard electrodes under any practicable conditions. It also reduces the amount of weld metal to be deposited and the total time of welding.

The tensile strength of the weld metal is higher than for the base metal used. Bend is satisfactory. Elongation in 2 in. is 20 to 30%. Weld metal is of X-ray quality.

This electrode can also be used for tack welding and gouging.

Data sheets on request. Weldwire Co., Inc., Philadelphia 25, Pa.

Electronic Timer

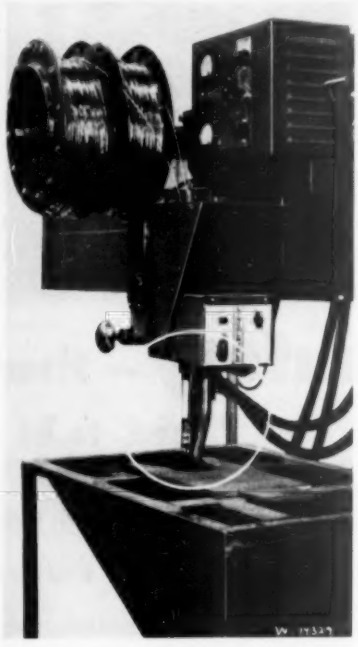
Photoswitch Electronic Timer 30HL1 makes available to industry timing control with unprecedented flexibility, extreme accuracy and long-life dependability. It is recommended over all other timers, electronic, synchronous motor, or mechanical, for process control machine timing and other industrial applications where long life, repeat-cycle operation or precise accuracy is a prerequisite.

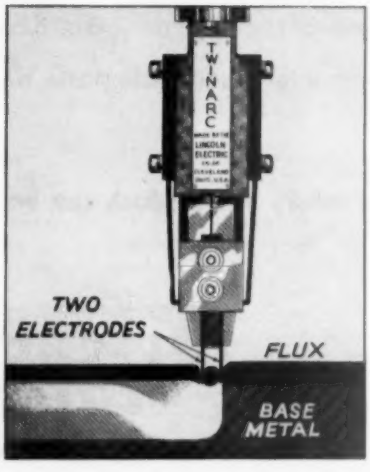
Type 30HL1 is an automatic timer for intervals from $^{1}/_{120}$ sec to 4 min. It provides four basic types of timing—Interval, Delayed Action, Automatic Repeat and Programming—as well as many variations of these four fundamental types. All these timing combinations are incorporated in this one timer and may be utilized by merely changing external connections to the terminal board. Thus type 30HL1 is a universal timer.

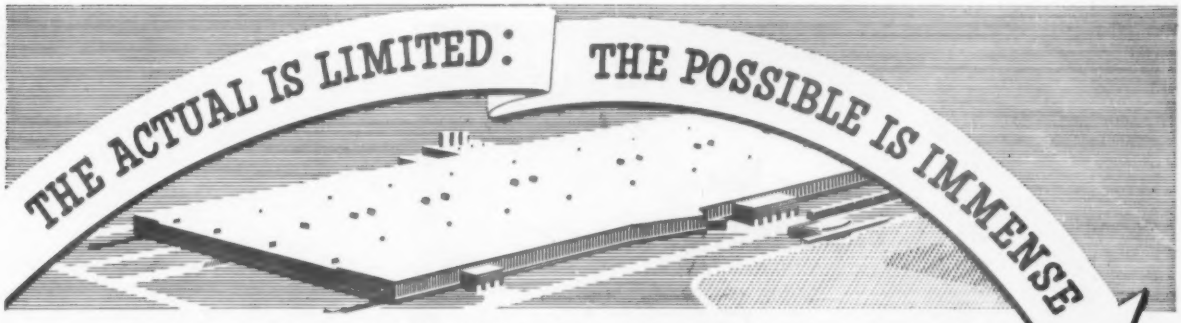
Type 30HL1 is described in Bulletin PC-5010.

Twinarc Welding

A new development in the application of hidden arc or submerged arc welding, announced by The Lincoln Electric Co. of Cleveland, Ohio, is said to increase the speed of automatic welding from 50% up. Twinarc welding, as the development is called, employs two small electrodes in place of a single larger electrode. The two electrodes are fed simultaneously through a single head and a single jaw. Both electrodes deposit metal in the weld crater. The higher currents possible with two electrodes increase the rate of metal deposi-







NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

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"MANUAL LINCOLNWELD" CUTS COSTS 67%

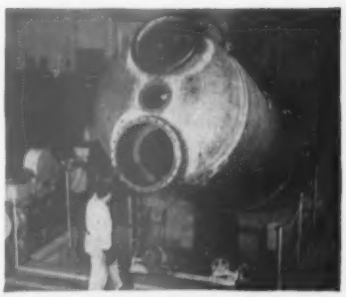

Fig. 1. Fabricates Tank *from ½" plate with "Manual Lincolnweld". Welding speed is 12 to 15 inches per minute at 400 amps.*

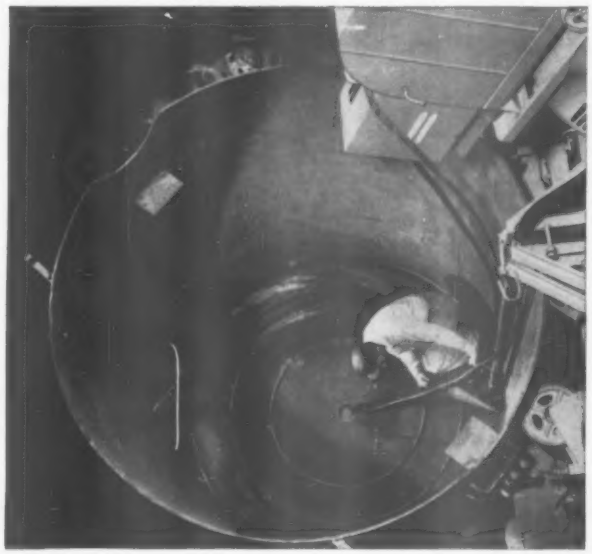

Fig. 3. High Current Density *on continuous electrode provides 100% penetration in one inside and one outside weld. "Hidden arc" welding in granular flux avoids arc rays and spatter . . . saves weld cleaning.*

USE of "hidden arc" welding with granular flux and positioners is cutting welding costs two-thirds in the fabrication of circuit breaker tanks at the Santa Clara plant of the Pacific Electric Manufacturing Corp. Exterior and interior welds are produced by positioning the welding gun of "Manual Lincolnweld" in a simple fixture. The work is then rotated beneath the welding gun with power rollers.

Currents of 375 to 400 amps concentrated on ¾" electrode produce full penetration at 12 to 15 inches per minute without need for plate preparation. Welds are self-cleaning to eliminate costly time in removing slag between passes as needed on conventional hand welding practice.

Undoubtedly results like these can be duplicated in your shop today. Consult a Lincoln welding engineer. Learn what new Lincoln developments in faster, easier welding can be applied to your operations to improve the quality of your work and cut production costs.

ELIMINATES JOINT PREPARATION

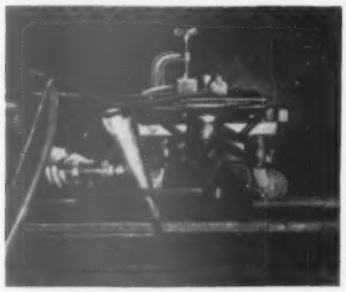

Fig. 2. Welding outside vertical seam *with "Manual Lincolnweld" gun mounted on simple rail fixture. Welding speeds are from 2 to 4 times faster than conventional hand welding.*

SAVES MANHOURS

GET THE FACTS—*Cost-saving benefits with Manual Lincolnweld are in Bulletin 1303*
Write on your letterhead to Dept. 1903

THE LINCOLN ELECTRIC COMPANY

CLEVELAND 17, OHIO

THE WORLD'S LARGEST MANUFACTURER OF ARC WELDING EQUIPMENT

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FOR WELDING AND CUTTING:

1. **Smith Regulators give accurate, dependable, trouble-free control of gas pressure.**
2. **Simplified design with no complicated mechanism . . . no delicate short-lived parts.**
3. **All parts easily accessible for quick cleaning, adjustment or repair.**
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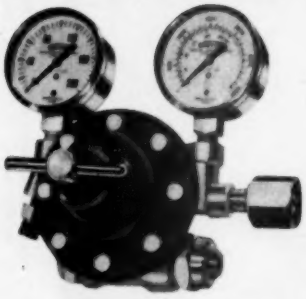

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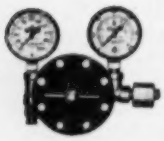
Single Stage or Two Stage . . . . SMITH REGULATORS are DEPENDABLE and require less maintenance.

This is precision equipment, based upon years of practical experience in the business and built to give years of service. Best proof of consistent satisfaction is the wide-spread popularity of Smith Regulators from coast to coast. This acceptance has been *earned*—on the job. One thing welders like is the ease of making repairs when necessary. It takes only 10 minutes to change a seat, 15 minutes for a new nozzle and 20 minutes for a diaphragm. No special tools necessary. No long delays. Smith Regulators keep production rolling.

A TYPE FOR EVERY NEED



Type BB Single Stage

Smith's Type BB Single Stage Regulators (Oxygen and Acetylene) provide an even delivery of gas for general welding and cutting. They are the old standby of the Welding Trade for 25 years.

Smith's Type BB-2 Two Stage Regulators soften the drop from high cylinder pressures to operating pressure without fluctuation for all types of welding and cutting as well as hard facing and alloy welding. Keeps torch flame at same adjustment without variation until torch is shut off. Smith also makes Line Regulators, Hydrogen Regulators, Air Regulators and other special purpose regulators. Write us for further information.

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tion, amount of penetration and, consequently, welding speeds.

Twinarc welding is recommended for use on butt or fillet welds in $^1/_4$ in. or thicker plate where the application is normal for automatic hidden or submerged arc welding. Typical of the speeds possible is that used in making a $^5/_{16}$-in. fillet weld, 15 ipm of 1500 amp.

A special electrode jaw, wire-feed rolls and wire guides adapt any standard Lincoln weld head for using two electrodes. The standard single-head controls are used as well as the standard d-c welding current generators. Currents up to 1500 amp can be used with Twinarc welding for which two generators may be paralleled or a single, 1500-amp unit may be used. The two-wire head will feed electrodes in $^5/_{64}$, $^3/_{32}$ and $^1/_8$-in. diam sizes. The two electrodes are fed down into the Twinarc jaw where the welding current is conducted into each electrode from the same contact block. The electrodes are pressed against each side of this contact block which determines the electrode spacing. This spacing is normally $^1/_2$ in. but can be adjusted where necessary. Both electrodes are regulated equally by the common arc voltage control. The welding current from the common welding generator automatically divides between them.

The electrodes are normally in line along the seam but may be skewed $^1/_8$ in. so that they are across the seam. This produces a wider bead. If a still wider bead is desired or if burn-through is a problem, the electrodes can be run side by side. Side-by-side operation is recommended for poor fitup. These electrode adjustments are the only extra adjustments needed other than those normally required for automatic welding.

In addition to increasing the speed of automatic welding, Twinarc welding is said to also facilitate welding on rusty or dirty plate, producing high-quality welds where normal single-arc technique would result in pinholes. The two arcs and resulting larger crater allow time for gases in the crater to be expelled.

All-Purpose Brazing Flux

A boon to welders who have been looking for a brazing flux that will really travel ahead of the filler metal and will not burn out is the completely new and shop-tested Johnson's All-Purpose Brazing Flux. This new, pure white flux is the result of intensive experimenting on all common metals and the final approved formula has shown excellent results on any brazing job in a welder's shop.

With this new flux, welders can braze cast iron, steel or stainless steel, malleable iron, brass, bronze, copper or copper alloys and also weld bronze, brass, copper and copper alloys.

The action of the premium grade chemi-

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Engineered FOR SMOOTH FLOW

TUBE-TURN Eccentric Reducers are designed with strong knuckle contours and as gentle transitions from large to small diameters as possible. In addition to providing smooth inner walls at the joints, these features hold turbulence and pressure loss to a minimum.

Efficient piping flow reduces pumping power requirements, and investment in equipment. For efficient, leakproof piping, specify welded systems—using TUBE-TURN Welding Fittings and Flanges.

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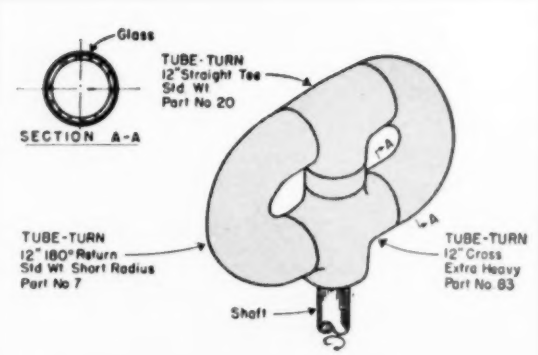
TUBE TURNS' *Engineering Service*

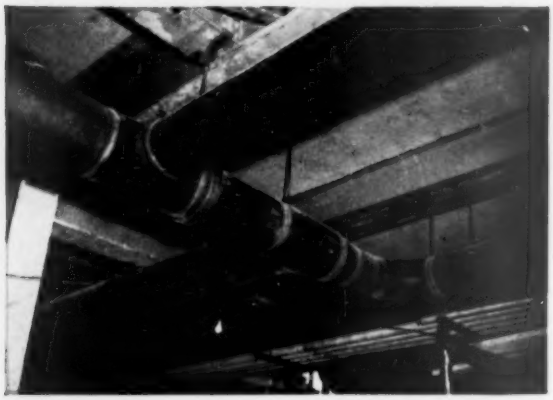
HELPS SOLVE A VIBRATION PROBLEM

TUBULAR CONSTRUCTION often solves tough machine design problems and here, as in piping problems, Tube Turns' Engineering Service is ready to help you! For example:

Vibration was cracking the glass coating of a plate type agitator for a brine tank in a chemical plant. After repeated replacements, the engineers decided to switch to tubular construction and called in Tube Turns' Engineering Service for design assistance. The resultant design, shown in the sketch, embodies great rigidity and is not affected by the vibration. The expensive maintenance caused by cracking of the agitator's glass coating was eliminated.



FABRICATION IS FAST. Field or shop fabrication of piping assemblies is easier when welders can count on the dimensional accuracy of TUBE-TURN Welding Fittings. True circularity and uniform wall thickness assure perfect lineup and fit.



AT GENERAL ELECTRIC. Two 16-inch steam mains, at boiler plant of the new G-E Appliance Park in Louisville, will help distribute 900,000 pounds of steam per hour efficiently. Welded piping, using TUBE-TURN Welding Fittings and Flanges, was specified for all critical lines in the new plant: high and low pressure steam, gas, domestic and mill water, and compressed air.

Want Material Data?

Tube Turns, Inc. has prepared a booklet containing dimensions and specifications of pipe and fittings available in various steels and wrought iron, including stainless steel, nickel alloys, etc. For a free copy, write on your letterhead to:

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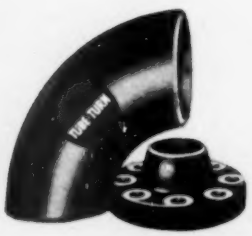
Company .....

Nature of business .....

Address .....

City ..... *State* .....



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TUBE TURNS, INC.

LOUISVILLE 1, KENTUCKY

cals in Johnson's All-Purpose Brazing Flux makes it flow more easily and smoothly ahead of the filler metal. At the same time this new flux cleans while it flows and wets the filler metal to the brazing surface.

To protect a weld area during the heating, Johnson's All-Purpose Brazing Flux may be applied as a paste made with either alcohol or water.

Johnson's All-Purpose Brazing Flux is packaged in 1-lb cans. Welders can get a generous, free trial supply of this new flux by writing Johnson Manufacturing Co., Inc., Mount Vernon, Iowa.

Band Saw Welder

A new, larger capacity Portable Band Saw Blade Welder has been announced by Brennen Manufacturing Co., 676 59th St., Brooklyn 20, N. Y. Designed to butt weld all blades from $^1/_{16}$ to $^3/_4$ in. it permits a wide range of work from intricate internal tool and die to power cut-off saws.

Compact and fully automatic, the Brennen Portable Band Saw Blade Welder is an all-purpose unit that will handle practically all requirements of the band saw user. Its complete welding facility for all types of band saw blades reduces filing time tremendously, cutting, as it does, so close to the line. Complete instructions are printed on the name plate and simplified controls assure uniform results at all times, even with inexperienced operators.

There is a built-in grinder, designed to remove flash from the weld, and a double gage for checking thickness of weld on flat saws. Because of its portability, it is possible to service a battery of band saws with the Brennen Welder. However, the removable back plate facilities permit permanent installation when desired.

Welding jaws are constructed of solid copper and the unit is housed in a welded steel case with long-lasting gray wrinkle finish. All-over dimensions of the Brennen Portable Band Saw Blade Welder are $7^3/_4$ x 12 x 7 in. Weight is 31 lb. Supplied with a handle for easy portability, the

Photo at Taylor-Winfield Corp.

HELPS YOU CALIBRATE

HERE, while the spot welder is in operation, a Brush Analyzer records amplitude and timing of both input and welding current on the same chart. By checking the wave shapes, inspectors are able to calibrate controls quickly, and assure top quality welds at all times.

Such exact data on welding variables helps you meet specifications exactly, and gives you written proof of performance. Guesswork is eliminated.

Versatile Brush Analyzers save you time in analysis of operation of all types of spot welding machines . . . and in studies of a-c or d-c voltages or currents, strains, stresses, displacements, and other static or dynamic conditions. Brush representatives are located throughout the U. S. In Canada: A. C. Wickman, Ltd., Toronto. For free bulletin write Brush Electronics Company, Dept. JJ4, 3405 Perkins Avenue, Cleveland 14, Ohio.

PIEZOTRONICS . . . Brush has prepared this informative 24-page brochure describing the functions and applications of piezo-electric materials. Write for your free copy — it may spark a product development idea.

BRUSH ELECTRONICS COMPANY

formerly The Brush Development Co. Brush Electronics Company is an operating unit of Clevite Corporation.

INDUSTRIAL AND RESEARCH INSTRUMENTS
PIEZOELECTRIC MATERIALS • ACOUSTIC DEVICES
MAGNETIC RECORDING EQUIPMENT
ULTRASONIC EQUIPMENT

welder operates on 110 v, a-c, 60 cycles and has an 8-ft cord and plug.

Further information may be obtained, upon request, from Brennen Mfg. Co., 676 59th St., Brooklyn 20, N. Y.

Soldering with a Cigarette Lighter

A new solder in paste form, trade named "Eutec-TinWeld" has been introduced by Eutectic Welding Alloys Corp., Flushing, N. Y. It is claimed to eliminate all soldering difficulties and reduce the number of operations to two, painting on the paste and applying the heat.

Technically, the material has extremely thin flowing properties with the solder so carefully balanced with its accompanying flux that the high wettability and capillary action permit it to penetrate the tightest of joints.

The parts to be joined are painted with the solder-paste and when heat is applied TinWeld becomes liquid. When the liquid darkens it is a sign the soldered joint is complete. There is no guesswork. There are no faulty joints it is claimed because the metal is automatically tinned when the paste liquefies, and the joint is made to a well-tinned surface.

These operations are practically simultaneous and any child old enough to be

trusted with matches can solder like a veteran. When heat is applied soldering is effected wherever the solder-paste has been painted.

Any source of heat may be used, it is reported, from an oxy-acetylene torch to a candle, and from a soldering iron to a cigarette lighter.

If a surface has to be tinned it may be painted with TinWeld and then placed in an ordinary kitchen oven. After heating the surface will have become tinned without pinholes or defects.

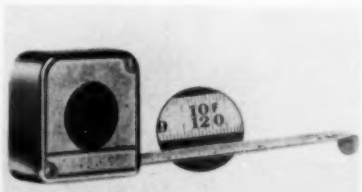
The home owner or the hobbyist, the sportsman or the industrialist will all find this unique material the answer to their soldering problems, the manufacturer states.

The low melting point of the past-solder makes it ideal for emergency repairs. Where sections are relatively thin the heat from a cigarette lighter will be sufficient to "get you home."

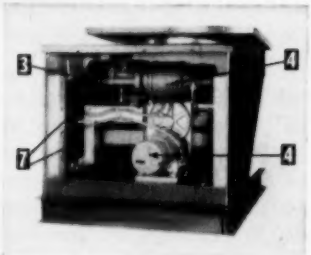
Rigid Welder's Rule

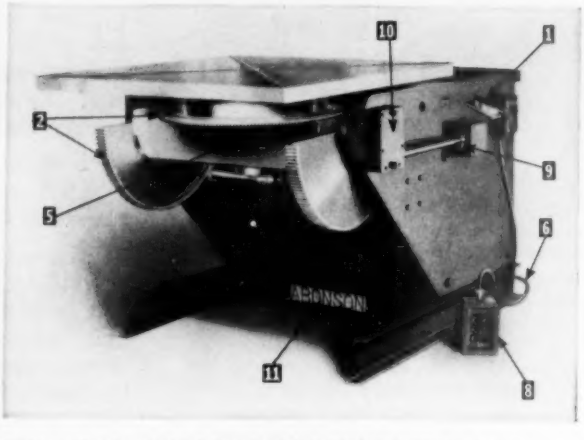
Atlas Welding Accessories Co., 707 E. Lewiston St., Ferndale 20, Mich., announce the addition of a new steel welder's rule to their line of welders' rules and accessories.

The new Atlas "Chief" is a 10-ft, spring recoil type rule. It has the extra strength



YOU CAN PAY FOR AN ARONSON WITH THE MONEY LOST IN ONE YEAR USING EQUIPMENT LACKING ANY OF THE FOLLOWING STANDARD ARONSON FEATURES





1 INFINITELY VARIABLE SPEED TABLE ROTATION from ZERO to Top Speed, at MICROMETER Control settings to 1% or less at ANY TIME.

2 PRECISION Steel GEARS, absolute MINIMUM BACKLASH, gives you SMOOTH WELDS, NO SKIPS, NO THINNING, NO BLOW-THROUGH.

3 POSITIVE DRIVES; No belts to slip and allow eccentric loads to over-run.

4 MAGNETIC BRAKES on Tilt AND on Rotation for SMOOTH, QUICK, PRECISE Stopping.

5 MERCURY GROUND Built Right In, not an attachment or a gadget to fail.

6 LOW VOLTAGE CONTROL CIRCUIT for safety of operation.

7 MAGNETIC REVERSING STARTERS for Trouble-Free Long-Life, mounted INSIDE.

8 OIL-TIGHT DUST-TIGHT Remote Push Button Station eliminates failure.

9 ANTI-FRICTION BEARINGS THROUGHOUT, Ball or TIMKEN Taper Roller Bearings.

10 LOW MAINTENANCE REQUIREMENTS, Gear Boxes PACKED FOR LIFE.

11 The KNOW-HOW and the SERVICE of a company devoted to POSITIONERS.

Aronson MACHINE CO. WORK WORK ARCADE, N. Y.

ITS JOB IS "HUSH-HUSH"

—but

RADIOGRAPHY makes its welds an open book

FEW people might know what this vessel is for. But its makers and those who use it know it is strong and safe — especially at its vital girth seam.

For radiography made certain that this weld was sound — that no gas porosities or lack of fusion lurked hidden to present hazards. X-ray inspection gave positive proof that all was well.

Because radiography provides such assurance, it has opened new fields for welders . . . has helped welding to win acceptance even in the manufacture of pressure vessels.

Radiography can increase your business and build your reputation for high quality work. If you would like to know how, get in touch with your x-ray dealer and talk it over.

EASTMAN KODAK COMPANY
X-ray Division—Rochester 4, N.Y.

RADIOGRAPHY
—another important function of photography

Kodak
TRADE-MARK

necessary to resist collapsing when extended either horizontally or vertically. Cumulative inches as well as feet are clearly indicated so that no conversions nor computations are necessary.

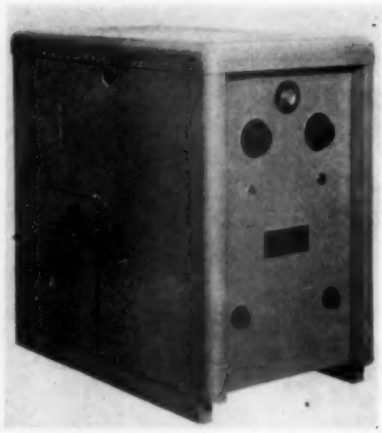
The tape is extra wide and finished in white with large, easy to read markings in black. An automatic brake holds the extended tape at any point without use of mechanical locks. The tip hook of the Atlas "Chief" rule swings to the side for obtaining accurate inside measurements.

D-C Power Source for Automatic Welding

A revolutionary new constant voltage d-c power source for all types of automatic welding is now in production by the Glenn Co. of Oakland, Calif.

Principal advantages claimed for the Glenn Constant Voltage Power source include automatic maintenance of the desired preset arc voltage regardless of fluctuations in arc length, high efficiency and high power factor which subsequently reduces input power requirements, and utmost simplicity of installation, operation and maintenance.

Five-hundred-ampere and 1000-amp continuous-duty rated models are available for submerged arc, inert gas and



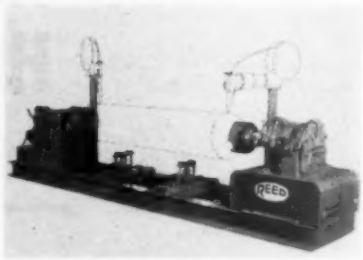
manually operated automatic welding. Units operate on either 240 or 480 v, 3-phase, 60-cycle alternating current.

Input requirements are but 25 amp at 480 v for the 500-amp unit operated at rated load. Operation consists of setting the desired preset arc voltage, and setting the current-calibrated dial of the rod feed motor to the desired current. There are no electronic devices or other delicate control mechanisms involved. Practically all existing automatic welding leads can readily be modified and equipped with the current-calibrated feed control used with the unit.

Literature and data may be obtained by writing to the Glenn Co., 3134 E. 10th St., Oakland 1, Calif.

Assembly Press and Girth Seam Welding Fixture

Illustrated is the latest addition to a line of special fixtures designed and built by the Reed Engineering Co. of Carthage, Mo., for assembly and automatic welding of light vessels, such as tanks for water heaters.



The fixture, known as the AW-205, handles tanks up to 24 in. in diam, 7 ft long, weighing up to 4000 lb. It features a 5-ton assembly pressure for pressing the tank heads on the ends of the shell, and two air-operated kick-out devices for rapid spotting and removal of the vessels. The headstock features a 10 to 1 variable speed range.

Tungsten Alloy for Inert-Gas Welding

A new tungsten zirconium alloy arc-welding rod that saves time and expense on inert-gas welding jobs was announced recently by Sylvania Electric Products, Inc. Called Zirtung, the new electrode features less contamination pickup on touch starting, continued steady arc and longer working life.

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National Carbide Company

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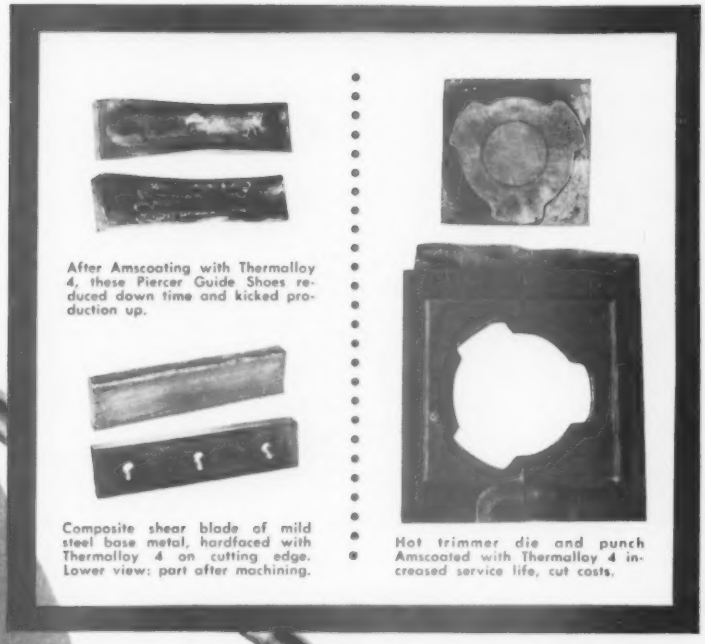


After Amscoating with Thermalloy 4, these Piercer Guide Shoes reduced down time and kicked production up.

Composite shear blade of mild steel base metal, hardfaced with Thermalloy 4 on cutting edge. Lower view: part after machining.

Hot trimmer die and punch Amscoated with Thermalloy 4 increased service life, cut costs.

BEAT HEAT WEAR and IMPACT with AMSCO THERMALLOY 4

If you have a wear problem involving high temperatures and requiring resistance to impact, this new Amsco hardfacing electrode can save you time and money

Elevated temperatures are tough to cope with in situations involving thermal shock, metal-to-metal wear, hot gas corrosion, high temperature oxidation—especially when you need great impact resistance. Here's where Amsco Thermalloy 4 can step in and give you longer service life, and big savings in time and money.

Supplied as both a composite coated electrode for electric welding or as a bare cast rod for gas welding, both types deposit a high-carbon stainless alloy containing chromium and nickel as the principle alloying elements. In many applications, it can replace expensive nickel base alloy materials. Thermalloy 4 is packaged in 50-lb. boxes or in 10-lb. packages in 50-lb. boxes. For detailed analyses and other pertinent information, write for catalog sheet on Thermalloy 4 or contact your nearest Amsco distributor.

AMSCOATING

THE RIGHT WAY TO SAY HARDFACING

AMERICAN Brake Shoe COMPANY

AMERICAN MANGANESE STEEL DIVISION

399 EAST 14th STREET • CHICAGO HEIGHTS, ILL.

Other Plants: New Castle, Del., Denver, Oakland, Cal., Los Angeles, St. Louis. In Canada: Joliette Steel Division, Joliette, Que.
Amsco Welding Products distributed in Canada by Canadian Liquid Air Co., Ltd.

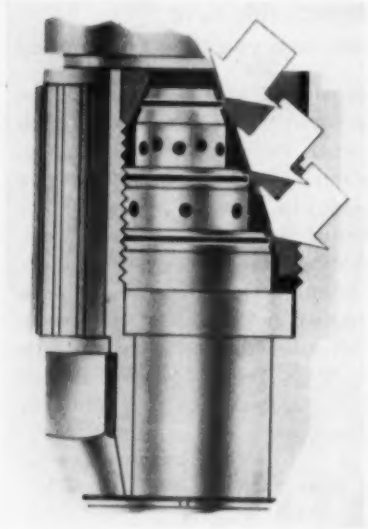
Zirtung was developed by Sylvania engineers because the tips of pure tungsten and thoriated tungsten rods become quickly contaminated. When contamination occurs, welding characteristics are so adversely affected that it is necessary to cut or break off the contaminated tip, thus consuming the electrode.

The new rods are the closest commercial approach yet made to a nonconsumable electrode, Sylvania engineers said. Tests showed only 1 in. of Zirtung rod consumed in a 12,000-in. semiautomatic welding job on two sheets of 0.035-in. stainless steel.

The slight contaminant pickup and nonwavering arc of Zirtung makes it ideal for use on all metals, particularly mild steel, aluminum and magnesium where contamination on touch starting is greatest. The new electrode operates on the same current range as thoriated tungsten and contains no radioactive materials. Zirtung rods are available at all Sylvania welding dealers.

Torch Mixer

A new welding torch mixer using "Gastite" servene seating rings has been developed by National Cylinder Gas Co., Chicago. The gasket-type seating, as contrasted with conventional metal-to-metal seating, permits the mixer to be attached to the torch handle without using a wrench. The mixer fits the company's standard Torchweld welding torch handle.



The seating rings have also been applied to a new model of the flame-cutting attachment for the same torch handle.

The new apparatus, according to the company, will be especially welcome to those in the metal-working trades whose work entails frequent changes from welding to cutting, and vice versa, using the same torch handle for both operations. It is also particularly suitable for outdoor work where dirt or sand particles may become lodged on metal seats, scoring the surface and making re-seating or replacement necessary.

Other advantages claimed for the gasket-type seating are leakproof connections, longer life for mixer and cutting attachment and lower maintenance costs due to the fact that the seating rings can be replaced easily and inexpensively.

Combination Cable Connector

Previously, the welding cable could be attached to the holder by soldering only. The new combination connector now provides for attaching to the welding cable as illustrated in the photograph—or by soldering as in the past—or by a combination of these two methods.

A large contact area between the holder and the cable and an extremely tight connection are made possible by the use of a large $^1/_2$-in. diam, fine-thread socket screw. Another equally important feature is that a hole is provided in the fiber handle for the insertion of a hex key wrench so that the tightness of the connection can be maintained in just a few seconds without disassembling the holder.

Bernard Welding Equipment Co., 10222 Avenue N, Chicago 17, Illinois.

Fully Insulated Electrode Holder

The Caddy Type B fully insulated electrode holders—300 and 400 amp—are designed to give welding operators the coolest operating, highest conductivity electrode holders in the market.

As shown in the cutaway model, all previous ideas in holder design have been discarded in achieving the cool operating high-conductivity goal.

The welding cable is carried through the holder body and attached to a completely replaceable beryllium copper jaw by means of a Cadweld solid copper connection that cannot be overloaded, cannot melt out or burn out, and can neither

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RESISTANCE TO IMPACT AND ABRASION . . .
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Manganal — the toughest metal known not harmed by heat — outlasts new hammers.
Workhardens to 550 Brinell — tensile strength to 150,000 p.s.i.
For greatest strength attach with Manganal Bare or Special Tite-Kote Electrodes.
FREE
Literature on latest methods for speedy and economical repair of worn equipment.
NEAREST DISTRIBUTOR UPON REQUEST
STULZ-SICKLES CO.
SOLE PRODUCERS 92 N. J. RAILROAD AVE. NEWARK, N. J.

Get Greater Stability, Versatility and Economy

WITH THE

LINK *STANDARD POINT HOLDER

for Multiple Spot Welding Machines

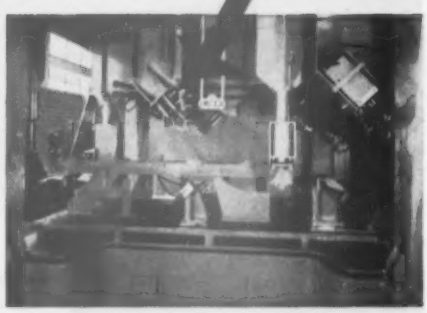
- *Offers universal water direction—eliminates pre-selection of point holders in replacement or repair*
- *Furnished with shanks in a variety of lengths—requires only ONE electrode length*
- *Simple, two-piece construction—fits standard type transformer cables*
- *Reduces maintenance costs—lowers replacement costs*

Answering one of the most critical needs in resistance welding, the patented Link Standard Point Holder is applicable in gun mounting; offers greater stability with offset points; effects greater economy in maintenance and operation of multiple spot welding machines.

Engineered to allow universal direction of water, this new Link development eliminates the necessity of pre-selecting point holders, thus allowing labor saving on-the-job repairs and replacements.

Essentially a screw-machine product of a simple, two-piece collet design, this sturdy Link Point Holder facilitates economical, time-saving replacement and repair of contact plate, or shank. Furnished with shanks in specified lengths, it permits the use of one electrode length, regardless of the space between cylinder and the part to be welded.

Further technical data on the Link Standard Point Holder available on request. Write today and submit your production welding problems to Link Welder for complete and competent recommendations.



Illustrations detail gun mounted application of Link Standard Point Holders on a multiple point spot welding press.

*Patented

LINK

"THE STRONGEST IN YOUR PRODUCTION CHAIN"

LINK WELDER CORPORATION

Designers and Manufacturers of High Production Welding Equipment

13684 WEST BUENA VISTA • • DETROIT 27, MICHIGAN

loosen or corrode. This results in (*a*) cool operation and (*b*) 80% conductivity at the electrode.

These electrodes are manufactured by Erico Products, Inc., 2070 E. 61st Place, Cleveland 3, Ohio.

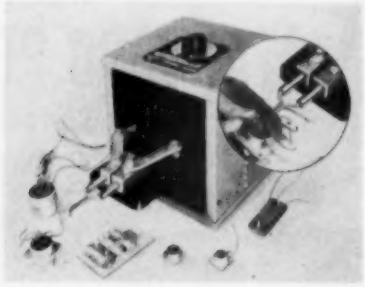
Protractor

Aronson Machine Co., Arcade, N. Y., manufacturers of welding positioners, announces a low-cost, money-saving extra for their line of welding positioners. The Model PRO Protractor is a quadrant marked off in degrees from 0 to 135 in 5-deg steps. The Protractor is attached to the tilt trunnion on the control side of the positioner where it is readily seen by the operator when tilting the table. Precise tilt angles are thus very easily obtained every time the table is tilted.

Welding research has shown that tilting the weld V downhill 10 deg results in over 50% increase in the weld speed. The PRO Protractor facilitates positioning the work for this 50% increase with assurance of welding in exactly the same attitude every time. The Protractor also serves a very useful purpose when setting up and when testing new weld processes and techniques.

Connector Soldering Machine

Joyal Products Inc., of Newark, N. J., announces the availability of its new 250W.AN Connector Soldering Machine. This equipment, which is priced at $100 F.O.B., Newark, N. J., can solder from 2 to 30 terminals, and more, on AN Connectors.



The equipment is particularly easy to use. The operator merely sets the heat and the solder, brings the work to the electrodes and presses the footswitch. The electrodes can reach into the tiniest areas where a regular soldering iron cannot penetrate. In the soldering of AN Connectors, the Joyal machine completes the work in one-third of the time formerly consumed, with no cold joints.

The electrodes will last for at least one year.

Inquiries and orders may be sent to Joyal Products, Inc., 56 Belmont Ave., Newark 3, N. J.

Stainless Steel Solder

Development of a new high capillary silver-bearing stainless steel solder which is applicable with a soldering iron or torch at 430° F, has been announced by All-State Welding Alloys Co., Inc., White Plains, N. Y. It has long been recognized, the company said, that on a wide variety of work, particularly on steel, stainless steel, copper and nickel alloys, a stronger "soft" solder would greatly reduce the need for the costlier materials and methods of brazing. Claims are that it costs much less than the silver brazing alloys, is easier and cheaper to apply and that it has somewhat the same affinity for all metals. Thin layers are strongest. It can be chrome plated.

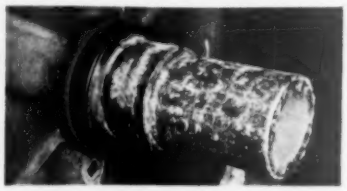
The new product will be listed as All-State No. 430 Silver-Bearing Stainless Steel Solder. It contains neither lead, zinc, nor cadmium. Unusual physical properties in the following test data derive primarily from its silver content and the unusual interalloys formed between different metals.

Copper to copper: Tensile, 14,300 psi; shear, 11,200 psi; and elongation in 2 in., 21%.

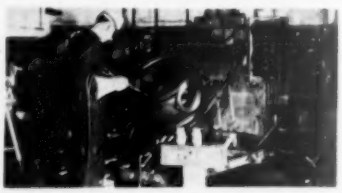
Average physicals on interconnecting stainless, copper, brass, etc.: Tensile 10,000–28,000 psi; shear, 10,000–15,000 psi, and elongation in 2 in., 10–28%.

Build up with...
All-State No. 13
Nickel-Silver ☑
Retemper...
None
Required ☐

• Dirt Mover Gears and Pinions • Finely Heat Treated • Reclaimed in 14 hr. with 25 lb. All-State No. 13 • Saved $510. net.



• Steam Processer Packing Gland Journal • None reclaimed before • 20 lb. of All-State No. 13 included in $300. overall repair • Saved replacement at $1300.

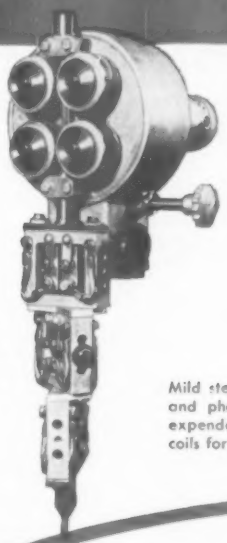


• Dripless Ball and Cone Valves • Rejections reduced to zero since adopting All-State No. 13 • High resistance to abrasion and galling is imperative.

All-State No. 13 Nickel-Silver Build-up Rod (and the No. 11 Brazaloy Flux that's always used with it) is sold just about everywhere. Over 600 All-State Distributors have it in stock. Write us for names of those near enough to you to be convenient. Ask for "Steel Booklet" to get complete application instructions.

ALLOYS FLUXES
All-State
ALL-STATE
WELDING ALLOYS CO., INC.
White Plains, N. Y.

Every Welding Need

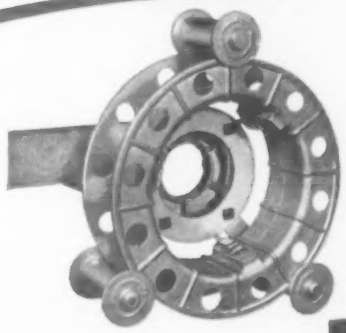


The Reid-Avery type 4R automatic head and control originally designed for Raco composite type A, may be used with equal success for lightly coated open arc or for submerged arc welding.

Raco composite type A heavy coated automatic (open arc) electrodes, a "Reid-Avery" first, can be furnished for all mild steel, low alloy high tensile, low hydrogen, hard surfacing and stainless steel grades.

Mild steel, alloy steel, stainless steel, aluminum and phosphor bronze wire are available on expendable wooden spools or in layer wound coils for gas shielded arc welding.

The Raco "free running" reels are especially designed for high speed automatic machines. The ball bearing trunnions enclose the coil so there is no over-run or loose strands and larger coils can be used. Changing coils is a matter of only a few seconds and no tools are required. Available in 12, 14, 25 and 36 inch sizes, for any weight from 50 to 200 lbs.



The Raco coils of wire for submerged arc welding have long been known for their uniform high quality and convenient, easy to handle package. Special attention is paid to the accurate weight, lay and temper of the wire so that the wire will accurately follow a seam. Available in mild steel, alloy steel and stainless steel.

Since 1919 Reid-Avery Company has specialized in the manufacture of all types of welding electrodes and wire. The large modern plant in Baltimore is equipped for wire drawing, annealing, pickling, coating, cutting, winding and packaging. Every phase of welding electrode and wire production is completely controlled from start to finish. You can be assured of uniform high quality and the best possible deliveries.

We also manufacture a complete line of manual electrodes in the following grades:
Raco Mild Steel, Raco Low Alloy High Tensile, Racocast for nonmachinable welds on cast iron, Raco Feral for welding aluminized sheets, Raco Low Hydrogen, Raco Hard Surfacing, Racolloy Stainless, Racolloy Nickel and Nickel 60 for machinable welds on cast iron.

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INCORPORATED
DUNDALK • BALTIMORE 22 • MARYLAND
SINCE 1919 PRODUCERS OF ARC WELDING ELECTRODES AND WELDING RODS

LIST OF NEW MEMBERS

Effective February 1, 1953

ANTHONY WAYNE

Dock, Lowell (B)
Marvel, Theodore (C)
Williams, Hubert W. (C)

BIRMINGHAM

McMahon, William R. (C)
Palmer, John W. (B)

BOSTON

Foberg, William M. (B)
Jefferson, James F. (B)
Mitchell, Charles L. (C)

CHATTANOOGA

Barker, William H. (C)
Naar, Peter S. (B)
Tucker, Dewey W. (B)

CHICAGO

Sims, Joseph F. (B)

CINCINNATI

Sandman, William L. (C)

CLEVELAND

Bennethum, Charles D., Sr. (C)
Bohn, William E. (C)
Cutting, Charles H. (B)
Furcolow, Francis G. (B)
Kulka, James M. (B)
Post, Jack C. (C)
Smith, Howard G. (B)
Stratman, Jack H. (C)
Templin, Gordon H. (B)
Venen, Arthur F. (C)

COLUMBUS

Corrigan, Walter J. (C)
Cossaboom, Gordon E. (D)
Davis, John R. (C)
Tozer, Alfred (C)
Welch, C. H. (B)
Wheeler, David L. (B)
Williams, Charles E. (C)

DETROIT

Brown, Norman S. (B)
Hendon, H. R. (C)
Hinderer, Robert E. (B)
Martin, John L. (B)
Mohri, August F. (C)

HOUSTON

Miller, Don P. (B)
Mott, A. L. (B)
Olson, Howard H. (B)
Stoffel, Albert (B)

INDIANA

Glass, Eugene H. (B)
Hebbe, George E. (B)

IOWA

Forney, Jack D. (B)

KANSAS CITY

Lewis, David H (C)
Maher, Joseph J., Jr. (B)

LONG BEACH

Davis, George S. (C)
Kupilik, O. W. (B)
Manary, Robert C. (B)

LOS ANGELES

Adams, Clarence (B)
Denny, George H. (C)
Reid, Earl R. (B)
Snow, James I. (C)

MAHONING VALLEY

Johnson, Forrest W. (B)
Owen, Roy (B)

MILWAUKEE

Croteau, Paul V. (C)
Dearing, Albert J. (C)
Duffy, H. J. (B)
Quartz, Herbert O. (B)
Wos, Stanley T. (B)

NEW JERSEY

Behnke, E. R. (B)
Brook, Webster William (B)
Finneran, William P. (B)
Geibel, Frederick T. (B)
Kovaric, Richard M. (B)
Lajevsky, Benjamin (C)
Livermore, Harry L. (B)
Mason, Joseph W. (B)
Merkovsky, Michael J. (C)
Moody, Elliott E. (C)

NEW YORK

Leffler, Robert (B)
White, Willard J. (B)

NIAGARA FRONTIER

Eber, Louis C. (B)
Hoglund, Thor F. (C)
Ritter, Don F. (B)

NORTHERN NEW YORK

Hardy, Samuel G. (C)
LaFlamme, H. K. (C)

NORTHWEST

Buettner, Paul W. (B)
Cave, Richard S. (B)
Forseth, George O. (C)
Griffis, Roger D. (C)
Keelor, W. B. (A)
Roy, Warren (C)
Taylor, Robert (C)

PASCAGOULA

Lyons, Robert Earl (C)
Mahony, Phil James, Jr. (B)
Scordino, Philip (B)

PHILADELPHIA

Darlington, J. B. (A)
Fox, Jerry F. (C)
Gibson, Walton (C)
Koch, Louis G. (C)
Schofield, Clayton (B)

PITTSBURGH

Barber, William R. (C)
Boyce, Joseph F. (B)
Smith, Robert S. (C)

PORTLAND

Babbitt, Earl J. (B)

PUGET SOUND

Dickerson, Donald R. (C)
Flaugher, Clarence H. (B)
Miller, Robert T. (C)

RICHMOND

Bloxton, S. E. (C)
Carle, Oscar, III (C)
Cox, B. A. (C)
Parrish, Lewis R. (C)
Sless, Harry (C)
Trombold, Robert M. (C)
Williams, Robert S. (C)

ROCHESTER

Quagley, Sam (C)

SAGINAW VALLEY

Bachman, Jack L. (D)

ST. LOUIS

Gabris, Vincent M. (B)
Hull, J. F. (C)
Schnell, Arthur H. (C)
Schuette, J. (C)
Sidney, John (C)

SALT LAKE CITY

Barkley, B. F. (B)
Romney, Clark (B)

SAN FRANCISCO

Balaam, Robert F. (B)
Hauck, Richard M. (B)
Olsen, Robert P. (B)
Olson, Ralph A. (B)
Twining, Fred (B)
Wadsack, E. T. (C)

SANGAMON VALLEY

Arnold, William L. (B)
Douglas, Earle P. (B)
Hedley, George A. (C)
Myers, Jeremiah W. (C)
Napier, Gustav (B)
Schiminski, William M. (B)
Songer, Charles Calvin (B)

SUSQUEHANNA VALLEY

Cornell, Cyrus J. (C)
Dombroski, John Joseph (B)
Packard, Carson (C)

SYRACUSE

Weyers, John William (C)

TOLEDO

Shanteau, Leland R. (B)

TULSA

Grand, David I. (B)
Hodges, Ted (B)
London, Jack J. (C)
Parrish, R. E. (B)

WASHINGTON

Thomas, Charles M., Jr. (C)

WESTERN MICHIGAN

Bain, George (C)
Doyle, Dewey I., Jr. (B)
Emerson, Harley C. (C)
Morton, James H. (B)
Morton, Robert E. (B)
Potter, Harry M. (C)

WICHITA

Prescott, R. M. (C)

WORCESTER

Braithwaite, Alexander (C)

YORK-CENTRAL PENNSYLVANIA

Martin, Lester B. (B)
Martin, Robert H. (B)
McNulty, Charles F. (C)
Powl, J. Frank (B)
York, Edward J. (B)

NOT IN SECTIONS

Burner, Kirk (B)
Hartman, Arie (C)
Meeuwisse, Cornelis Henri (B)
Vales, Julio (B)
Van der Spuy, Sybrand Johannes (B)
Welter, George (B)

Members Reclassified

During the month of February

DETROIT

Brooks, Richard E. (C to B)
Field, Hugh J. (C to B)

NIAGARA FRONTIER

Dieboldt, Fred (C to B)

Kelvinator makes good use of Robotron

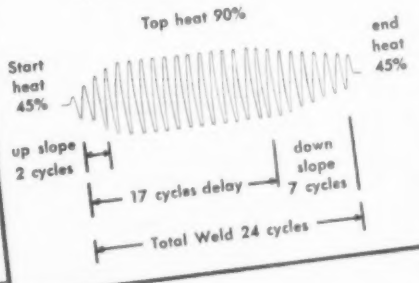
ENGINEER'S LOG BOOK

Customer: Nash-Kelvinator Corporation
Detroit, Michigan

Problem: Welding and sealing Fusite glass-to-steel hermetic terminals to Kelvinator refrigerator compressor housing.

Solution: Robotron NEMA 3B non-synchronous electronic timers with "up-down slope control" and ignitron contactor combination did the job.

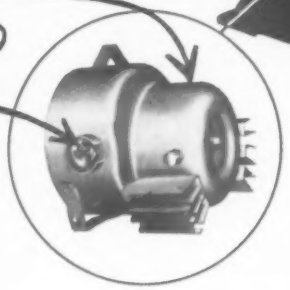
Welding Schedule:



Concentric Welder manufactured by Resistance Welder Corporation, Bay City, Michigan.

The Kelvinator compressor housing

The Fusite terminal



Kelvinator is in full production "Cushion-Welding" the Fusite terminal to the refrigerator compressor housing without breakage or "leakers"!

Through the use of Robotron up-down slope timing controls, Kelvinator accomplishes a delicate production welding job without critical welding schedule or critical weld set-up procedures:

- Reducing possibility of leakers.
- Reducing possibility of breakage.
- Eliminating metal distortion and internal metal stresses.

"Cushioned Power" helps Kelvinator control WELD-ZONE heat to an unbelievable degree.

Let Robotron engineers solve your welding problem — ask about our "ON THE JOB APPROVAL PLAN."

'Write or wire for further information today.

FINEST IN INDUSTRIAL ELECTRONICS

Robotron® CORP.

21300 West Eight Mile Road
Detroit 19, Michigan

NEWS OF THE INDUSTRY

Resistance-Welder Control Seminars

Company representatives from some of the nation's largest users of electrical and electronic equipment attended a recent series of seminars on resistance-welder control, sponsored by the Square D Co.

The sessions, which were attended by representatives of some of the nation's largest firms, were held under the direction of J. W. Brown, supervisor, Resistance Welder Control Seals for Square D, and D. H. Miller, Industrial Control Sales Manager of Square D's Western Division.

Among those who attended the seminars in Los Angeles and San Francisco were executives in the aircraft, automotive, metal and electronic industries including: Chrysler Corp., Ford Motor Co., Kaiser Mfg. Corp., Dodge Motor Car Division of Chrysler, Naval Supply Center, Bethlehem Steel, W. R. Ames Co., Seedorff, Inc., Varian Associates.

"Midwest Piping" Changes Name

By vote of the stockholders at a meeting on Feb. 16, 1953, the name "Midwest Piping and Supply Co., Inc." has been changed to "Midwest Piping Co., Inc." according to an announcement by A. G. Stoughton, President and Chairman of the Board of Directors.

Mr. Stoughton adds that there has been no change in ownership, management, personnel or activities of the company. . . nor is any contemplated. The only change is the name. . .to make it more accurately descriptive of the company's operations.

"This name change merely recognizes the fact that Midwest has grown away from the supply business. While we still conduct supply operations in the St. Louis area, it is a comparatively small part of our business. For many years our major activity has been the fabrication and installation of piping and the manufacture of welding fittings," says Mr. Stoughton.

Liquid Oxygen Plant at Butler, Pa.

The recently completed Air Reduction Sales Co. liquid oxygen plant in Butler, Pa., has commenced delivery of oxygen to industrial customers it was announced here recently by H. R. Salisbury, president.

According to Mr. Salisbury, the plant, which represents a capital outlay of "several million dollars" supplies oxygen directly by pipe line to two Butler customers, Armco Steel Corp. and Pullman Standard Co. In both cases these companies use oxygen in the processing of steel.

The plant, which operates continuously, has a rated capacity of 100 tons of liquid oxygen per day, making it, according to Mr. Salisbury, Air Reduction's largest liquid oxygen installation.

Conventionally, oxygen is delivered in gaseous form by steel cylinders' tube trailers or pipe lines. Liquid oxygen permits an expansion of delivery distances and offers additional economy and convenience in transportation and storage. The oxygen is generally converted to gaseous form for use.

The Butler plant will also produce argon and nitrogen.

Argon, an inert gas, is used primarily in the gas-shielded electric arc process and the electronics industry. Nitrogen, also an inert gas, provides an inert atmosphere where fire hazard or chemical oxidation must be avoided.

Electronic "Nose" Finds Leaks

A nearly foolproof method of finding leaks in anything from a football to a complicated coil of pipe or a huge distillation tank has been developed with a gas that once served only as the cold-making agent in refrigerators.

The new test medium is Du Pont "Freon-12" fluorinated hydrocarbon which, under pressure, is a colorless, virtually nontoxic and odorless liquid, but which changes to a gas when released from pressure at room temperatures. Its use as a leak detector stems from its ability to seek out and escape through the finest openings in almost any material. The exact location of such leaks can be found quickly with an electronic device or a gas-burning torch whose flame changes color in contact with the nonflammable "Freon."

Halide torches, small hand-held lamps in which methyl alcohol, acetylene or propane burns with an almost invisible flame, have been used for many years to detect leaks of "Freon" in refrigeration systems. The sensitive flame turns green or blue-green in the presence of the gas, and experts can tell by the flame color just how big the leak is.

Another use is in the testing of complicated pipe coils or pressure vessels too large and cumbersome to be filled with compressed air and dunked in a liquid bath where escaping bubbles would indicate leaks. Today, such precision manufacturers as Foster Wheeler Corp. of Carteret, N. J., carry out tests on tanks as high as a two-story building by filling them with a mixture of "Freon" and air, then carefully inspecting likely leak points, such as joints, fittings or welds, with one of the electronic "noses."

Morrison Visits Nassau

I. Morrison, Vice-President of Morrison Steel Products, 601 Amherst St., Buffalo, N. Y., explains to G. M. Coleman, Executive Assistant Manager of the Fort Montagu Beach Hotel, Nassau, Bahamas, where Mr. Morrison spent his February vacation, that the fender on the fire engine at the East Bay Street Station, Nassau, was manufactured by his company in the year 1916 or 1917. Mr. Morrison recognized the work of his company while on a bicycle sight-seeing tour around this picturesque British colony. The fire engine itself, built by the American LaFrance Co., is still giving good service. Mr. Morrison states that a few years later his Company employed welding in the fabrication of these fenders.

30 YEARS IN THE WELDING FIELD

is a long, long time!

In many industries, a span of 30 years is a "short" length of time. But, in welding, the three decades after 1923 represent the great period of growth in this field—a span that might equal hundreds of years in another industry. For in this period preceding and following World War II, welding has come to the forefront as a superior method of fabrication. Through its exclusive qualities, its developments, its limitless applications, welding has contributed speed, power, strength, and stupendous savings in time, labor and materials to the products of the metal working industry.

In this period, we have seen the construction of all-welded ships, welded buildings, welded airplanes and many other modern-day welded wonders. In this era, the welding industry has grown out of its swaddling clothes into a giant of unlimited capacity and utility.

Burdett, celebrating its thirtieth anniversary, has grown step by step with the industry, developing products and facilities to meet new requirements. From five to five hundred employees... from one to over one thousand different products is a measure of our growth, but more than that it signifies the spirit of service upon which this organization was founded. Young in years, old in experience, Burdett faces the future with confidence, knowing that welding has shown the world only a small sample of the work of which it is capable.

every product... and every process... to fit every purpose best!!

the BURDETT oxygen company

GENERAL OFFICES: 3333 LAKESIDE AVENUE, CLEVELAND 14, OHIO

BRANCHES
AKRON CINCINNATI
COLUMBUS MANSFIELD

PLANTS
CLEVELAND, DAYTON & YOUNGSTOWN, OHIO
LOS ANGELES, CALIFORNIA

WELDING EQUIPMENT • INDUSTRIAL GASES • SAFETY EQUIPMENT

Fingertip heat control

right at the work-with the P&H Welding Twins

equipped with Dial-lectric Control

Dial-lectric Control is an exclusive P&H feature that helps you weld faster, easier, better — at less cost!

P&H AC WELDER

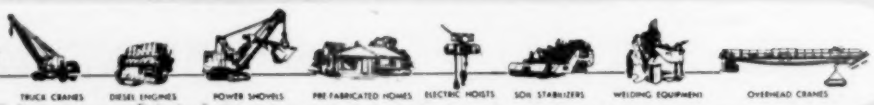
As easy as tuning your radio — just turn the radio-type knob of the Dial-lectric Instantaneous Remote Control (or step on a foot treadle), to adjust heat accurately. Easy, quick-start arc. No hard-working cranks to turn. No moving parts to cause delays or maintenance expense. Sizes up to 625 amps., NEMA rated. Connectable to 220 and 440 volts.

P&H DC RECTIFIER WELDER

Also equipped with hand-or foot-operated Dial-lectric Control, to give the welder fingertip heat control at the work. No hard-working cranks to turn. No moving parts to wear out. Saves on power costs under load — and during idle and no-load periods. Protects the primary input line against unbalanced conditions. Three sizes, 200, 300, and 500 amps., NEMA rated.

P&H WELDING DIVISION
HARNISCHFEGER CORPORATION
4551 WEST NATIONAL AVENUE • MILWAUKEE 46, WISCONSIN

the P&H *Line*



Steam Pipe Line Welded

Worker welds lengths of $2^1/_2$-in. wrought iron pipe for the steam line on one of the new railroad cars being manufactured by The Budd Co. for the Chicago, Burlington & Quincy Railroad. Floor of car in accompanying photograph is upside down to facilitate installation of equipment. When finished, it will be reversed—roof, ends and sides added to complete car body. To protect against corrosion, wrought iron was specified for steam lines and air brake piping in each of 34 ultramodern cars to be used for four trains of the CB&Q lines. Known as the Kansas City Zephyrs, the trains will be placed in operation early in 1953, providing day and night service between Chicago and Kansas City.

Eutectic Names "Agathon" as "Miss Welder of 1953"

Glamorous, lovely, delectable Barbara Nichols, better known as "Agathon" in such Broadway stage and TV successes as "Pal Joey," the "All Star Revue," the Jimmy Durante Show, and the Jerry Lester Show, was officially named "Miss Welder of 1953" by the National Eutectic Welders Club on February 14th, Valentine's Day.

Miss Nichols was selected as "the girl we would like most to weld with" by the graduate body of professional welders representing nationwide industry and the armed services who attended the Eutectic Welding Institute to learn the most modern techniques and methods of metal joining with "low-temperature welding alloys."

"Agathon's" selection was the result of the welders' heartfelt recognition of her "outstanding qualities of beauty, physical charm, poise, determination, endurance, meticulousness, emotional stability, ready wit and unselfishness" . . . all exemplary of the "girl we would most like to weld with."

Rene D. Wasserman, president of the Eutectic Welding Institute and the company bearing the same name, presented a scroll to Miss Nichols, and officially proclaiming her "Miss Valentine" as well as "Miss Welder" on behalf of the welders of America.

Three-Day Welding Clinic Set in Indianapolis

A three-day welding clinic coinciding with the house warming and formal opening of a new warehouse of the Steel Sales Company of Indiana at 2185 N. Sherman Dr., Indianapolis, on Apr. 15, 16 and 17, was announced recently by Fred W. Walters, President of the Steel Sales Corp.

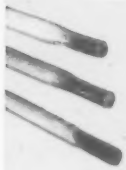
Welding experts of leading metal companies, as well as producers of various welding and accessory equipment, will participate. These include: International Nickel Co., Aluminum Company of America, Crucible Steel Corp., Lukens Steel Corp., American Platinum Works, P. R. Mallory, Driver-Harris, Alloy Metal Wire and Metal Forming Corp.

Engineers representing these companies will answer questions relative to the welding, soldering, and brazing of nickel, aluminum, copper, brass, Monel, Inconel, stainless steel, clad steels, cast iron, ductile iron, and alloy irons such as Ni-Resist, and the low- and high-alloy steels. Practical demonstrations will be given.

P&H

Welding Equipment speeds production schedules, cuts costs

P&H LOW-HYDROGEN ELECTRODES



13 types for high-strength welds on problem steels, steel castings, nickel-alloy steels, chrome-moly steels, .40 carbon castings, high-hardenable steels, aircraft and similar steels.

P&H POSITIONERS

Position heavy weldments for economical down-hand welding. Complete range of sizes to handle work from 2500 to 36,000 lbs. — remote-control and hand-operated models.

P&H WN-301 *Engine-Driven* DC ARC WELDER

2- or 4-Wheel Mountings

Portable. Equipped with Dial-electric Control, for fingertip heat control at the work — gives you faster, better welding. Runs at only 1750 rpm. Welding service range, 60-375 amps, NEMA rated.

Ask your P&H representative or distributor for complete information, or write for free bulletins.

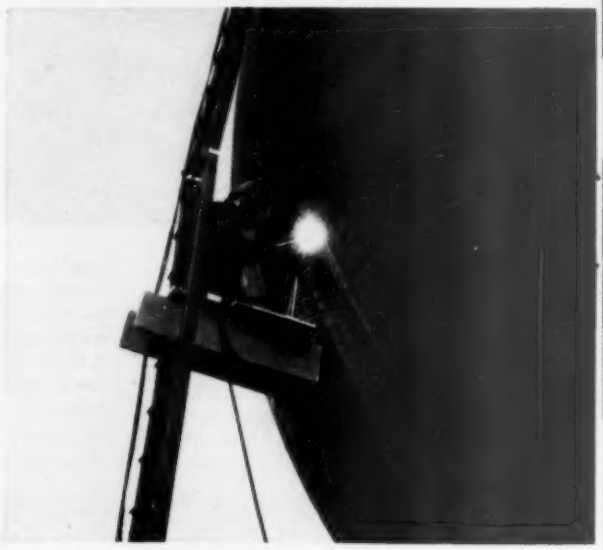
P&H WELDING DIVISION

HARNISCHFEGER CORPORATION

4551 W. National Ave., Milwaukee 46, Wis.

2494A

Welding Arcs



REPORTS FROM WELDORS ON JOBS LIKE THESE INDICATE THAT NEW GENERAL ELECTRIC TYPE W-610-A

Now—Better Welds Faster with G.E.'s

Pipelines, shipyards, fabricators, and builders report many benefits from new AWS Class E-6010 electrode:

PIPELINES Operators like W-610-A electrode because it's easier to use and produces top-flight welds. Slag is easy to remove and "pinholing" is not a problem. The coating does not break down even at high currents. X-rays show excellent deposits and very low porosity.

SHIPYARDS "Now you've got something," say shipyard weldors. On overhead butt welds—one of the toughest shipyard jobs—W-610-A is free of "fingernailing" and "wandering arc." No trouble is caused by reaction pitting. Good set-up prevents undercutting.

FABRICATORS "This is really it! Gas pockets are practically a thing of the past." Weldors prefer the new W-610-A over any other Class E-6010 in the shop. Even on dirty, rusty steel, this new G-E electrode is easy to use. And burn-off rates are high, increasing production.

CONSTRUCTION Weldors welcome the new W-610-A because it's easy to use in all positions and its ability to take high currents speeds construction.

Users have backed up these reports by placing large orders for W-610-A for immediate shipment. But don't take our word on the new W-610-A—find out for yourself. General Electric Co., Schenectady 5, N. Y. 710-4

You can put your confidence in—

GENERAL ELECTRIC

News

Information on equipment, electrodes and accessories from G.E., pioneer in arc welding

ELECTRODE WILL BE INDUSTRY'S NEW QUALITY STANDARD

New W-610-A Electrode

TRY NEW W-610-A YOURSELF at our expense

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General Electric Co.

Why not try this new W-610-A electrode on your toughest mild-steel jobs? Just ask for a free sample from your nearby G-E Welding Distributor. You'll find his name here, and also in the yellow pages of your phone book under "Welding Equipment—General Electric." Contact him today.

Here's the name of your G-E Welding Distributor—

Alabama: Birmingham—Alabama Oxygen, Young & Vann Supply; Mobile—Turner Supply

Arizona: Phoenix—Consolidated Welding Supply

California: Fresno, Los Angeles, Oakland, Sacramento, San Diego, San Francisco, Ventura—Victor Equipment

Colorado: Boulder, Colorado Springs, Denver, Durango, Ft. Collins, Ft. Morgan, Greeley, LaJunta, Longmont, Pueblo—Hendrie & Bolthoff

Florida: Ft. Pierce, Hollywood, Key West, Melbourne, Tampa, Vero Beach, West Palm Beach—Florida Gas & Chemical

Georgia: Atlanta, Macon—Welding Supply & Service; Augusta—Marks Oxygen & Welding Supply; Columbus—Williams Welding Supplies

Idaho: Boise—Olson Manufacturing

Illinois: Chicago, Moline, Morton—Machinery & Welder

Indiana: Evansville—Drill Master Supply; Ft. Wayne, Indianapolis, Richmond—Sutton-Garten; South Bend—Perry Welding Sales & Service

Iowa: Des Moines—Machinery & Welder

Kansas: Coffeyville—Thompson Bros. Supply & Welding Equip.; Hutchinson—Kopper Supply

Kentucky: Louisville—Reliable Welding; Paducah—Henry A. Petter Supply

Louisiana: Alexandria, Shreveport—Hughes Oxygen; New Iberia—Welders Supply; New Orleans—Equitable Equipment; Opelousas—Daigle Welding Supply, Lake Charles—Welders Equip.

Maryland: Baltimore—Arcway Equipment

Massachusetts: Boston—New England G-E Welding Sales Division

Michigan: Detroit—Welding Sales & Engineering; Grand Rapids—Miller Welding Supply

Minnesota: Duluth—W.P.&R.S. Mars; St. Paul—Production Materials

Mississippi: Jackson—Jackson Welding & Supply

Missouri: Kansas City—Hohenschild Welders Supply; St. Louis—Machinery & Welder

Montana: Billings—Valley Welders Supply, Butte, Great Falls—Montana Hardware

Nebraska: Lincoln—Lincoln Welding & Supply, Omaha—Baum Iron

New Jersey: Kenilworth—Welding Sales

New Mexico: Albuquerque—Industrial Supply Co.; Hobbs—Western Oxygen; Las Cruces, Silver City—Car Parts Depot, Inc.

New York: Buffalo—Welding Equipment Sales; Syracuse—Welding Engineering & Equip.

North Carolina: Charlotte—Dixie Gases, Gastonia—Gastonia Motor Parts

North Dakota: Bismarck, Fargo—Acme Welding Supply; Fargo—Dakota Electric Supply

Ohio: Akron, Cincinnati, Cleveland, Columbus, Dayton, Mansfield—Burdett Oxygen; Toledo—Odland Iron Works

Oklahoma: Tulsa—G-E Welding Sales Division

Oregon: Eugene, Portland—J. E. Haseltine

Pennsylvania: Philadelphia, Pittsburgh—Arcway Equipment

South Carolina: Columbia, Greenville—Welding Gas Products

South Dakota: Deadwood—Hendrie & Bolthoff

Tennessee: Chattanooga, Knoxville, Nashville—Welding Gas Products; Memphis—Delta Oxygen

Texas: Abilene—M&M Welding Supply; Alice, Corpus Christi—Crane Welding Supply; Alpine, El Paso, Marfa, Pecos—Car Parts Depot; Amarillo—Tex-Air Gas; Brownsville, Harlingen—Acetylene Oxygen; Dallas—Hill Equipment & Supply; Houston—G-E Welding Sales Division; Lubbock—Welders Supply; Midland—West Texas Welders Supply; Odessa, Pecos—Western Oxygen; Plainview—Plains Welding Supply; San Angelo—Southwestern Welding Supply; Snyder—Western Welding Supply; Texarkana—Hughes Oxygen; Wichita Falls—Nortex Welding Supply

Utah: Salt Lake City—The Galigher Co.

Washington: Seattle, Spokane—J. E. Haseltine

West Virginia: Bluefield—Bluefield Supply; Charleston—Virginian Electric, Huntington, Logan—Logan-Hardware & Supply

Wisconsin: Milwaukee—Machinery & Welder

Alaska: Anchorage—Northern Supply

Canada: Toronto—Canadian G.E.

Hawaii: Honolulu—American Factors, Ltd.

SECTION NEWS AND EVENTS

as relayed to C. M. O'Leary

Carilloy

Bethlehem, Pa.—Approximately 30 members and guests of the *Lehigh Valley* Section were present on February 2nd for dinner and to hear R. L. Deily, AWS, of Air Reduction Co., as the coffee speaker. His topic of discussion was "Fire and Earth."

Leon C. Bibber, AWS, Welding Engineer, U. S. Steel Corp., gave an illustrated talk on "Carilloy," the new high yield strength alloy steel, developed by U. S. Steel.

Mr. Bibber discussed the numerous tests which have been conducted to determine the weldability of this steel. These tests having proved conclusively that "Carilloy" in either the welded or unwelded state remains ductile at atmospheric temperatures. He gave the chemical composition and mechanical properties; a yield of 90,000 to 100,000 per square inch; a tensile of 105,000 to 115,000 per square inch. The price is approximately $0.10 per pound. At the present time, it is available in plate only, with symmetrical shapes to be made at a later date. Cold forming of this steel on material 3/4 in. thick has been done with good results.

He questioned the need for stress-relief annealing when using this steel because of its tough, ductile behavior. Some bend tests were conducted on plate with gas cut edges, with no detrimental effects.

A lively discussion followed.

Rigid Frame Arch Dome

Boston, Mass.—The world's largest rigid arch dome is the central feature of "Shoppers' World" in Farmingham, Mass., and the steel frame was fabricated and erected by A. O. Wilson Structural Co. of North Cambridge. Albert O. Wilson, Jr., AWS, and Donald B. Wilson presented a paper on the welding of this rigid frame arch dome at the January 12th meeting of the *Boston* Section held in the auditorium of the Westinghouse warehouse, South Boston. Albert Wilson talked about design and fabrication and Donald Wilson told about how the erection problems were solved and the structure very successfully completed. The Section was pleased to hear some of its own members present such an interesting subject.

It houses the larger portion of the Jordan Marsh store and was built of that type of construction because of the uniqueness and, therefore, the attractiveness to prospective shoppers. It has served that purpose and helped to draw people to the store.

Coffee speaker was Artie Gore, National League Umpire. Artie gave a very entertaining talk on how Big League baseball games are conducted and the umpire's problems. He also told some very interesting anecdotes and with his good humor in answering questions he gave a very enjoyable talk.

Steel

Boston, Mass.—At the regular dinner meeting of the *Boston* Section held on February 9th P. Edward McKenna, Chairman, Boston Section and Assistant District Manager of U. S. Steel, Supply Division of U. S. Steel Corp., presented a supply division training film entitled "Steel—Foundation of Civilization." This new strip film is in color, much of it in hand drawings and is synchronized with voice recordings. It describes steelmaking from ore to finished product in an extremely interesting and enjoyable way. The various ways of making steel are shown and described. The iron carbon diagram is explained, and the effects of alloying elements, heat treatments, etc., are also discussed. The film was extremely interesting and enjoyable.

Coffee speaker was Irvin Noyes Gould of the Gould Sales Promotions, Boston. Mr. Gould spoke on political promotions. He had promoted the campaign of Mr. Herter for Governor of Massachusetts, and previous to that he was in charge of publicity and promotions for "Citizens for Eisenhower." His talk was very interesting and entertaining and together with his answers to questions he gave an excellent account of how political campaigns are managed.

Metallurgy of Welding

Bridgeport, Conn.—"Recent Developments in Metallurgy of Ferrous Welding" was the subject of the talk given by Robert H. Aborn, AWS, Assistant Director of Research, U.S. Steel Co., Kearny, N. J., at the February 19th meeting of the *Bridgeport* Section held at Rapp's Restaurant, Shelton. Mr. Aborn gave a brief outline of welding processes and their basic metallurgy, then a discussion of the metallurgical characteristics of ferrous weld metals and the nature and prevention of cracking. He also discussed the factors controlling heat input and dissipation and how it can be controlled by welding procedure. A high-speed color movie film made at a speed of 3000 frames per second showing the arc behavior of four different classes of electrodes accompanied Mr. Aborn's talk.

Coffee speaker was Mr. Smith of the U. S. Internal Revenue office who gave some excellent ideas on income tax filing procedures.

Inert Arc Welding

Buffalo, N. Y.—At the January 22nd meeting, approximately 100 members and guests of the *Niagara Frontier* Section, heard Arthur N. Kugler of the Air Reduction Co. speak on "Inert Arc Welding."

Mr. Kugler, who is a recognized authority in this field, briefly discussed the history of inert arc welding. This process started in the early stages of World War II, primarily as a tool for welding magnesium. A tungsten electrode was used with DC-RP, and a monatomic gas was used for shielding. The process gradually expanded to other metals and other types of power. The use of alternating current provided a problem of starting and maintaining the arc which was solved by superimposing a high-frequency voltage on the conventional power supply. This technique resulted in considerable use of the process of welding aluminum. The subse-

Left to right, John C. Kaluzny, Technical Chairman; R. P. Gehring, Section Chairman; A. N. Kugler, Speaker, and C. E. Jackson, Past Section Chairman

quent use of DC-SP permitted welding of other metals at high speeds and with good penetration. A primary advantage of the inert arc process is the complete absence of flux of any kind.

A fundamental requirement of inert arc welding is that a monatomic gas be used for shielding. Both helium and argon are commercially used at the present time. The welding characteristics are quite different with these gases. Helium results in higher arc voltage at a given arc length, thus providing more power. On the other hand, argon provides a more stable arc under certain conditions. For example, the use of alternating current with superimposed high frequency is not practical with helium. Some typical examples of current and gas combinations used for various metals are as follows:

Metal	*Current*	*Gas*
Magnesium	DC-RP	Argon or helium
	AC	Argon
Aluminum	AC	Argon
Copper, nickel, and stainless steel		
Heavy sections	DC-SP	Helium
Light sections	DC-SP	Argon

A new development in this field is that of tandem welding, in which two tungsten arcs are used, each being controlled and shielded independently. This permits faster speeds and a better appearance as the first arc gives penetration and the second arc smooths the weld.

Mr. Kugler showed a number of slides illustrating applications of both the inert-gas-shielded tungsten arc and inert-gas-shielded consumable-electrode arc. He also showed a 20-min movie entitled "Tool of Many Uses," which described the inert-gas-shielded consumable-electrode welding process.

A lively question-and-answer period followed Mr Kugler's presentation.

Aircomatic Welding

Cincinnati, Ohio.—At the regular meeting of the *Cincinnati* Section held on January 27th in the Engineering Society Headquarters, Donald P. Carey gave a paper on "The Development and Welding with the Aircomatic Process." The Aircomatic process has been the particular specialty of Mr. Carey and as a result he has accumulated a vast store of practical data in addition to the theoretical considerations underlying the Aircomatic process. Mr. Carey demonstrated his talk by showing two sound films in color entitled "The Tool for the Job" and "The Tool of Many Uses."

Stainless and Heat-Resistant Steels

Cincinnati, Ohio.—A joint meeting of the *Cincinnati* Section was held on February 12th with the American Society for Metals' local chapter. Speaker was George Linnert, AWS, Armco Steel Corp. (Rustless Division), whose subject was "New Developments in Welding Stainless and Heat-Resistant Steels." Mr. Linnert used slides to illustrate his talk. One hundred and thirty-two members and guests of both Societies were present.

Structural Welding

Dallas, Tex.—The January 13th meeting of the *Dallas* Section was addressed by Van Rensselaer P. Saxe, AWS, Consulting Engineer, of Baltimore, who spoke extemporaneously on the subject of "Structural Welding." The meeting was held in the Mercantile Bank Auditorium.

Powder Washing

Dallas, Tex.—"Powder Washing and Powder Lancing" was the subject of an excellent presentation given by R. S. Babcock, AWS, Linde Air Products Co., Newark, N. J., at the February 24th meeting of the *Dallas* Section held in the Venus Restaurant.

Applications of Metals

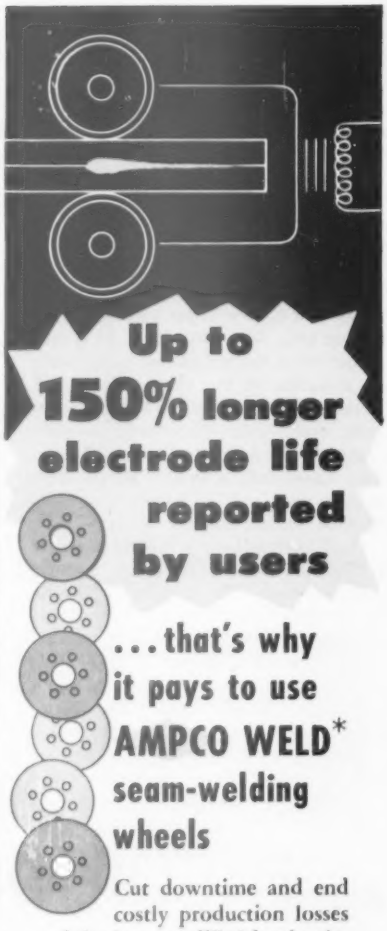
Denver, Colo.—The *Colorado* Section held its monthly meeting on February 10th at the Oxford Hotel in Denver. Technical speaker was Glenn A. Fritzlen, Assistant Technical Director, Haynes Stellite Co., Kokomo, Ind. New methods, applications and research were covered by Mr. Fritzlen in his talk entitled "New Methods and Applications." Coffee speaker was Sgt. Leonard Johnson of Traffic Engineering of the Police Department. Sgt. Johnson spoke on traffic problems.

Jigs and Fixtures

Des Moines, Iowa.—Anthony K. Pandjiris, AWS, President of the Pandjiris Weldment Co., St. Louis, Mo., gave an informative talk entitled "Set the Pace—Win the Race" at the January 22nd dinner meeting of the *Iowa* Section held in Younker's Dining Room. The nontechnical presentation, attended by 40 members and guests, covered the application of weld positioning for increased production, improved confort and safety for the welder, and increased applicability of automatic and semiautomatic welding processes. Featherweight subassemblies to final assemblies weighing tons may be quickly and efficiently positioned for welding. The talk was accompanied by slides and followed by a question-and-answer period.

Arc Welders

Des Moines, Iowa.—H. J. Bichsel, AWS,



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Arc Welding Section of Westinghouse Electric Corp., gave an excellent extemporaneous technical talk on "Rectifier Direct-Current Arc Welders" at the dinner meeting of the *Iowa* Section held on February 12th, at Younker's Dining Room.

Mr. Bichsel used both slides and movies to illustrate his talk. He began by explaining the basic operational principles of the Westinghouse Type RA Rectifier D-C Welders. These welders operate from a 3-phase alternating-current power supply and deliver direct current to the welding arc. They differ from M-G sets in that there are no moving parts (with the exception of the blower motor and fan) and are theoretically static type electrical equipment. The welder consists essentially of a 3-pole contactor, a 3-phase delta transformer, a 3-phase reactor with moving core and a 3-phase full-wave selenium type rectifier.

The Type RA Rectifier Welder possesses an auxiliary feature known as the Arc Drive Control. The Arc Drive may be set to produce an electrical transient characteristic which may be advantageous for certain welding operations. When set, the control provides an additional surge of current as the arc becomes shorted during globular transfer or by actual contact of the electrode with the work. This additional current helps to clear the arc path and prevent arc outages or electrode sticking.

Ultra slow motion movies were shown illustrating the globular transfer under various operating conditions with and without the aid of the Arc Drive Control. The arc drive circuit is composed of a 3-phase half-wave rectifier energized by tertiary windings on the main transformer, a control rheostat and a protective thermoguard.

Thirty-eight members and guests were present for this meeting.

Ladies' Night

Detroit, Mich.—On Saturday evening, May 16, 1953, the *Detroit* Section will present its annual Ladies' Night party. The party will be held at the Latin Quarter, location of the 1951 and 1952 parties. The evening will consist of dinner, music, entertainment and dancing and the general assortment of lovely door prizes to be given to the "Lucky Number" ladies. Bring your own bottle, setups will be sold. Tickets are being sent through the mails. All tables will be reserved. Only 650 tickets will be sold.

Hard Facing

Erie, Pa.—Howard S. Avery, AWS, of the American Brake Shoe Co. gave an excellent extemporaneous talk on "Hard Facing" at the February 17th meeting of the *Northwestern Pa.* Section.

Mr. Avery is a graduate of Virginia Polytechnic Institute and has been with the Metallurgical Department of the American Brake Shoe Co. since 1934. Since then he has been identified with their research in various aspects of industrial wear. Heat- and wear-resistant alloys have engaged a large share of his attention. He is a member of various technical societies and is now Chairman of the AWS-ASTM Filler Metal Subcommittee on Hard Facing Alloys.

A film "No Finer Electrodes Made" was shown through the courtesy of the Alloy Rods Corp.

Weld Tests

Grand Rapids, Mich.—The *Western Michigan* Section met on January 26th at the Grand Villa. The new meeting place proved an excellent one for food and a place to hold the technical session. Sixty-nine members and guests enjoyed an excellent roast beef dinner. After dinner they were entertained by the "Ionians" who provided some good old-time barbershop harmony.

The technical session was addressed by

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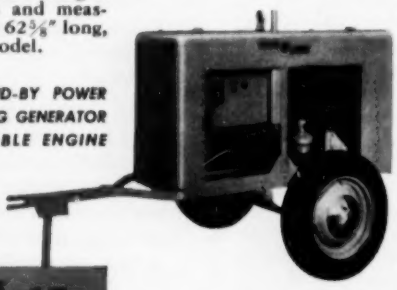

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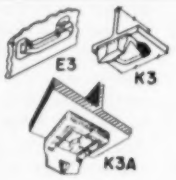

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Dr. Stanley Knapp, President of the Industrial Testing Laboratory of Grand Rapids. Dr. Knapp's talk on "Weld Tests and Causes of Weld Failure" proved very interesting, as was witnessed by the large crowd in attendance. Dr. Knapp used slides to illustrate his remarks.

Dr. Knapp formerly was Chief Research Physicist in charge of Physical Testing Labs at the Buick Motor Car Co.

Process Control

Grand Rapids, Mich.—The *Western Michigan* Section held their regular monthly meeting on Monday evening, February 23rd, at the Grand Villa in Grand Rapids. Present for the dinner were 63 members and guests. They were joined by others for the coffee talk and technical session.

The coffee speaker was E. J. Houghton, Sales Manager of the Folding Steel Chair Division of the Ionia Mfg. Co. His film "Mexican Jungle Adventure" was filmed entirely by himself on one of his hunting trips into the Mexican Jungle in search of the Jaguar. It was very interesting and drew plenty of applause when finished.

The Technical address was given by Stewart Spice, AWS, Welding Engineer of the Buick Motor Car Co. of Flint, Mich. His subject was "Process Control in Welding." This subject was of interest to many as shown by the excellent crowd in attendance. The slides shown in connection with the talk displayed the several methods and techniques used by the Buick Motors in their welding processes. At the close of the meeting several remained to question Mr. Spice further and all who attended agreed that this had been a very instructive session.

Metallurgy

Hartford, Conn.—The February 12th dinner meeting of the *Hartford* Section was held at the Rockledge Country Club, West Hartford. Technical speaker was G. R. Brophy, AWS, International Nickel Co., whose subject was "Metallurgy of Ductile Iron."

Through the courtesy of the Allegheny-Ludlum Steel Co. a sound motion picture film, entitled "Welding of Stainless Steel," was shown after the meeting.

Powder Cutting

Houston, Tex.—The February meeting of the *Houston* Section of the AWS was held Feb. 25, 1953, at the Ben Milam Hotel. The principal speaker of the evening was R. S. Babcock of the Linde Air Products Development Laboratory in Newark, N. J. His subject was "Cutting and Scarfing," a subject on which he has had much experience. Mr. Babcock is the Laboratory

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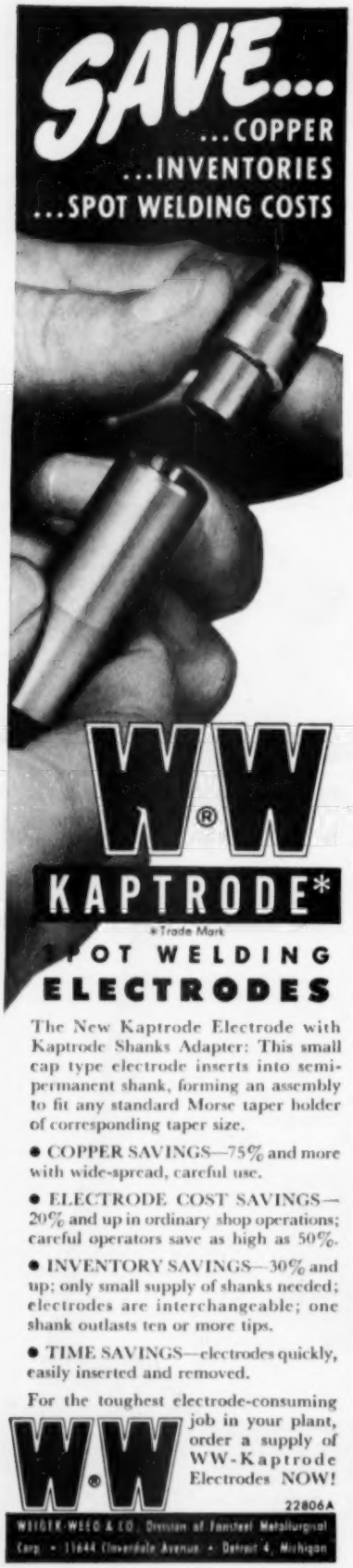
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Mr. Babcock covered cutting and scarfing operations used in the various steel mills, including the latest equipment for powder cutting and powder washing. His talk was accompanied by slides and motion pictures on powder washing and the piercing of concrete with the oxygen powder lance.

A steak dinner, keg and movie preceded this most interesting talk by Mr. Babcock. Ninety-two members and guests were present.

Quiz Program

Louisville, Ky.—A quiz program was conducted by Vice-Chairman E. S. Elwood of the Louisville Section on February 24th in which four members, Jesse Hawkins, Linden Bock, Clarence Schiller and Mason Noyes, participated.

Questions pertaining to resistance welding, inert arc welding, cutting and alloy welding were among those raised and satisfactory answers were obtained from the panel.

As was evident at previous meetings of this type, the program proved very interesting and informative and undoubtedly will be repeated in the future.

Educational Course

Milwaukee, Wis.—The *Milwaukee* Section Annual Educational Course, held at Marquette University, has been completed.

January 12, 1953, was "Airco Night." Two new films were shown. "Burning Blades" was a fine 16-mm color-sound film on the many applications and types of equipment manufactured by Air Reduction Co. The second film, "Tool of Many Uses," covered copper, aluminum and bronze Aircomatic welding. Some of the pictures were taken in Milwaukee shops thus having added interest. C. A. Nolan, AWS, and J. Huna, AWS, of Airco assisted with short talks and answered questions.

On January 19th Mr. Ogden, AWS, President of Aladdin Rod and Flux Mfg. Co., Grand Rapids, Mich., gave his lecture and demonstration: "Welding of Zinc Base Alloys and Brazing of Aluminum Die Cast Without Flux." (The fellows just didn't know when to go home.)

On January 26th Austin Hiller, AWS, Welding Sales Engineer of General Electric, presented his lecture "Toughness in Welds." He gave a very lucid description of the parts that proper weld technique and rod selection play in fabrication of the hard jobs, locked-in stresses and their results.

February 2nd was the windup with a plant tour arranged by H. E. Bailie, AWS, of Nordberg Mfg. Co. The tour of their new fabricating plant was well attended and for the students and members who had never seen heavy fabricating, forming and welding operations it was most educational.

Welding Titanium

Newark, N. J.—The Feb. 17, 1953, meeting of the *New Jersey* Section was held at the Essex House in Newark, N. J., with approximately 85 members in attendance.

The Guest Speaker was C. B. Voldrich, AWS, Chief Welding Engineer of Battelle Memorial Institute, Columbus, Ohio, who gave a talk on "Welding of Titanium and its Alloys." The lecture was illustrated with slides and covered a complete review of the present developments in welding titanium and its alloys. In addition to reviewing the metallurgical and technical phases of the subject, Mr. Voldrich dealt with many of the application and technique problems involved. An active discussion period followed the formal talk.

The achievements of Mr. Voldrich in welding won for him the outstanding honor of presenting the "Adams Lecture" before the 1952 annual meeting of the AMERICAN WELDING SOCIETY.

The "After Meeting" snack of coffee, beer and pretzels was enjoyed by all.

Aircraft Welding

Oklahoma City, Okla.—The fifth meeting of the season of the *Oklahoma City* Section was held on Friday, January 30th, at Jack Barnes Clubroom. Speaker at the meeting was Thomas M. Hopkins, Metallurgist at the Tinker Air Force Base. He discussed some of the problems that have arisen at the Tinker Base. Two films "Power for Peace" and "Out of Position Welding" were shown through the courtesy of the Tinker Air Force Base.

Welding Stresses

Pascagoula, Miss.—About 60 members and guests were present at the November 5th meeting of the *Pascagoula* Section to hear J. E. Durstine, AWS, Lincoln Electric Co., Birmingham, Ala., present an excellent discussion on "Welding Stresses" which was demonstrated by polarized light and plastic models.

An after-meeting feature was the showing of a 16-mm sound color film entitled "Heavy Bulk Materials Handling" through the courtesy of Heyl and Patterson, Inc.

John F. Bryan, Jr., AWS, of the American Bureau of Shipping, introduced the new members before the technical meeting.

Alloy Electrodes

Peoria, Ill.—The regular monthly dinner meeting of the *Peoria* Section was held on January 21st at the Mecca. Technical speaker was R. K. Lee, AWS, who spoke on the subject "Recent Developments in Alloy Electrodes."

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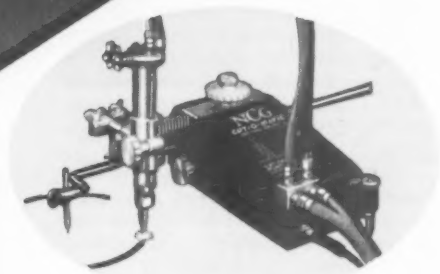

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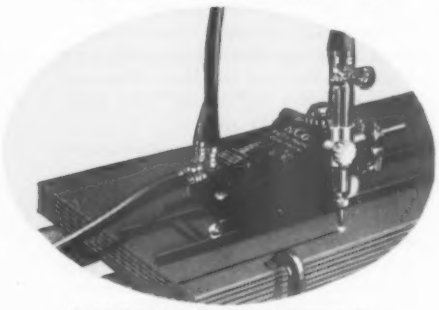

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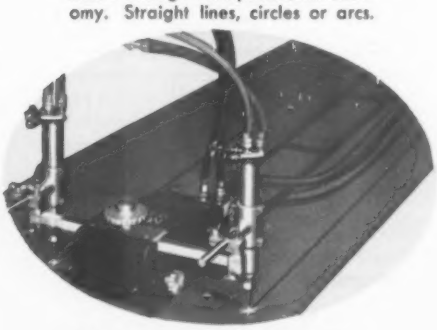

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Mr. Lee received his Bachelor of Metallurgical Engineering degree from Ohio State University in 1935 and then worked for five years as Research Engineer with the Steel and Tube Division, Timken Roller Bearing Co. The past twelve years have been devoted to arc-welding electrode research and development and during the past six years he has been associated with the Alloy Rods Co.

He is past chairman of the York-Central Pennsylvania Section of AWS and represents his company on the AWS filler metal specification committee in New York, as well as the Classification and Color Chart Committee, Arc Welding Section, National Electrical Manufacturers Assn. He is also serving on the Ordnance Advisory Committee on the Welding of Armor.

In addition to the AMERICAN WELDING SOCIETY, he is a member of the American Society for Metals and the Engineering Society of York.

Fabrication Problems

Philadelphia, Pa.—The *Philadelphia* Section held their February meeting at the Engineers Club Monday, February 16th, with a good attendance. Prior to the regular meeting, the officers met for a Board Meeting and discussed, among other business, ways and means to encourage a stronger attendance and more active participation at both their regular monthly meetings and also the panel board meetings.

A dinner was served prior to the meeting with more than 25 in attendance. The meeting opened promptly at 8:00 P.M. The Section was honored to have as their guest speaker R. W. Bennett, AWS, Chief Quality Control Engineer, American Locomotive Co., Dunkirk, N. Y. Mr. Bennett was introduced by Ralph Bradway, Co-Chairman of the local section. The timely selected subject of Mr. Bennett's talk was entitled "A Metallurgical Approach to Welding and Fabrication Problems." This subject, being a fine one to say the least, was amply illustrated with a number of slides pertinent to the welding of pressure vessels subject to extreme low-temperature operation. The Philadelphia Section is indeed most appreciative to Mr. Bennett for his superb presentation of the above subject.

Following the talk, a most interesting question-and-answer period took place until 9:45 P.M. The meeting was then adjourned with a rising vote of applause and refreshments were served.

Nondestructive Testing

Phoenix, Ariz.—On the evening of February 18th, the regular monthly meeting of the *Arizona* Section was held in the Aluminum Room of the Hotel Westward Ho. Following the dinner, John Dyer, AWS, introduced the speaker of the evening, Robert G. Strother, West Coast Manager of the Magnaflux Corp.

Mr. Strother spoke on "Nondestructive Testing of Weldments." His talk was particularly well presented and was augmented by very descriptive slides. With his broad experience and background in the aircraft, automobile and ordnance industries he was particularly well qualified to tell the Section of the various processes available for detecting defects in welds.

All of those present were quite surprised at how the electronic field has entered into weld testing and that defects are seen in a viewer much like the home television set. The Section was greatly appreciative of Mr. Strother's visit.

Steel Castings

Pittsburgh, Pa.—The regular monthly

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SW-159	310
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SW-161	317
SW-162	308
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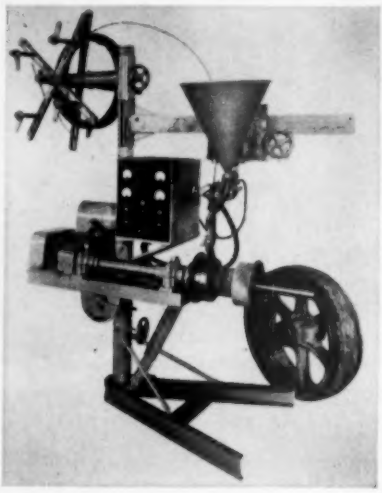

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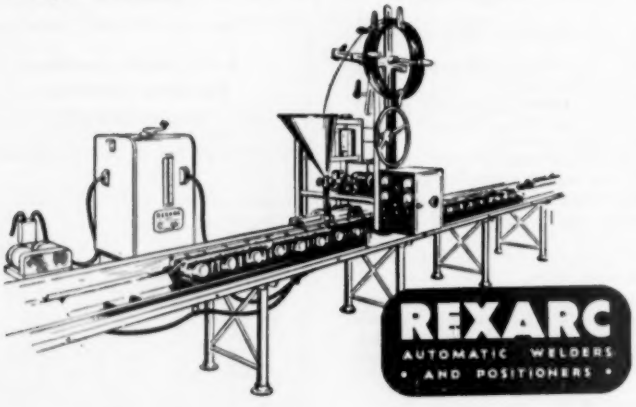

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meeting of the *Pittsburgh* Section was held on February 18th in the auditorium of the Mellon Institute of Industrial Research. A get-together dinner at the Hotel Webster Hall preceded the meeting.

"Welding of Steel Castings" was the subject of the presentation given by James H. Lowe of the Steel Founders' Society of America, Cleveland, Ohio. Mr. Lowe used slides and motion pictures to illustrate his remarks.

Mr. Lowe discussed the added flexibility in design of materials due to recent developments in arc welding and electrode composition, stressing particularly the cast-weld and composite fabrication process. He pointed out the advantages of this process, types of design most suitable and the many examples where used. He also discussed the limitations of cast-weld and composite fabrication, showing examples of toughness of cast parts used in welded structures.

The Handy & Harman sound color film entitled "Silver Brazing" was shown by William Kauffman, AWS Williams & Co., Pittsburgh.

Past-President Charles H. Jennings was present at both the dinner and meeting and spoke briefly before the meeting.

Welded Structures

Phoenix, Ariz.—Van Rensselaer P. Saxe, AWS, Consulting Engineer, Baltimore, Md., gave a very interesting presentation on "Welded Structures" before a special joint meeting of the American Institute of Architects, American Society of Civil Engineers, National Society Professional Engineers and the AWS. This special meeting was arranged by the *Arizona* Section and held at the Hotel Westward Ho. The attendance was over 150.

Mr. Saxe's discussion on welded structures brought out the simplicity and economy of welded structures. He stated that the engineer can show a savings of 20% when welding is used over riveted or bolted connections. He proved this by 100 different slides showing structures that his firm had designed for welded construction and brought out that his first welded structure was designed and constructed in 1927, and that his office has designed and supervised construction of over 1200 welded structures of all types since then.

Mr. Saxe pointed out that structural steel has strength, is uniform throughout, has exceptional endurance, does not deteriorate under loads and stresses, has great toughness, adaptability to all sorts of building construction versatility as by using welding any member can be fabricated to suit the engineers creative design. With all these qualities and steel's elasticity combined with welding, steel is one of the best structural materials. Using modern methods of joining structural steel

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Photo courtesy H. C. Phelps, Welding Engineer

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employing automatic welding and semi-automatic welding, special plate girders and rigid frame members can be fabricated with a substantial savings both in shop fabrication and on-the-job erection.

The speaker explained that welding has opened up new horizons for steel fabrication, that it is now possible for the architect and engineer to conceive any kind of design. Only with the design of welding can this be accomplished.

He also stated that in the early days they would make up two sets of drawings, one design for welding and the other designed for riveted construction. In no case did the welded design lose out. The ultimate consumer got a better building with a cost savings generally of 20% and higher. He mentioned that engineers of today would not have to be welding experts to design for welding. He brought out that the manual *Steel Construction* of the AISC and the AWS specifications on steel construction make detailed information readily available to any architect or engineer. If they use this information and the knowledge that they have with a little changing in their thinking they will be able to come up with amazing results.

Everyone agreed this was a most interesting meeting.

Ladies' Night

Saginaw, Mich.—A Ladies' Night dinner-dance party was held on February 14th at the Rolling Greens Golf Club, Saginaw, by the *Saginaw Valley* Section. One hundred and eighty members and guests were present. This was the most successful party of this type ever held by this Section. Everyone had an enjoyable evening.

Nickel Alloys

San Francisco, Calif.—The regular monthly dinner meeting of the *San Francisco* Section for February was held on the 20th at the Engineers Club. This meeting was held on Friday instead of the usual fourth Monday due to the fact that Washington's birthday fell on that Monday. An excellent, extemporaneous discussion on "Maintenance Welding of Nickel, High Nickel Alloys and Cast Iron" was presented by K. M. Spicer, AWS, Development & Research Division of The International Nickel Co., Inc., New York. A goodly number of slides showing many typical and practical applications were used in connection with Mr. Spicer's presentation.

Through the courtesy of the San Francisco Police Department a 20-min., black-and-white, 16-mm film in sound, entitled "Traffic with the Devil," which was produced by the Los Angeles Police Department, was shown. This film shows actual scenes from the investigation of automobile accidents in the Los Angeles area. A very timely and instructive story.

Welded Structures

San Francisco, Calif.—A joint meeting of the *San Francisco* Section with the Structural Engineers Assn. was held on Tuesday, February 3rd, at the Engineers Club. One hundred and thirty-nine members and guests of both Societies were present at dinner and one hundred and fifty-three attended the meeting.

"Welded Structures" was the subject of an excellent talk given by Van Rensselaer P. Saxe, AWS, Consulting Engineer, Baltimore, Md. There was a great deal of interest in this subject by the Structural Engineers' Assn. of Northern California and the speaker was excellently qualified to present his subject. He has lived long enough to know from experience what can and cannot be accomplished in this field. He, therefore, speaks with top authority and does not gloss over any points of disadvantage; and, likewise, he is very frank to express his convictions of what is sound practice in his chosen field.

In 1920 Mr. Saxe opened his office as Consulting Engineer in Baltimore specializing in structural steel and reinforced concrete work of all types. His first welded structure was designed and completed in 1928 and since that time his office has designed and supervised the construction of over 1200 welded structures of all kinds.

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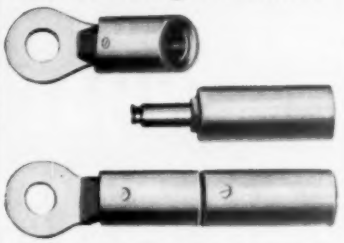

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New Section

Tucson, Ariz.—Joseph A. Pruitt, AWS, was elected chairman protem of the newly formed *Tucson* Section of the AMERICAN WELDING SOCIETY, Tucson, Ariz., at the organizational meeting held February 3rd. Mr. Pruitt will serve until the first regular election which will be held in May, in accordance with the newly adopted by-laws.

Sixty-three persons became charter members of the Tucson Section at this organizational meeting which will make the Tucson Section one of the largest in the Rocky Mountain area. Mr. Pruitt stated that many more applications are in the hands of prospective members, and with this and the many charter members indicates that the Tucson Section will number more than 100 within three months.

Mr. Pruitt will be assisted with the following slate of officers who will also serve until May: Oliver M. "Mutt" Golay, first vice-chairman; W. C. "Prof." Curry, second vice-chairman, who is an engineering professor at the University of Arizona; Charles Condron, treasurer, and George Hunt, who heads the welding department at the Tucson Vocational High School, as secretary. Mr. Pruitt is Sales Manager for Arizona Welding Equipment Co.'s Tucson branch, the largest welding supply house in the state of Arizona, serving the entire state as well as parts of old Mexico.

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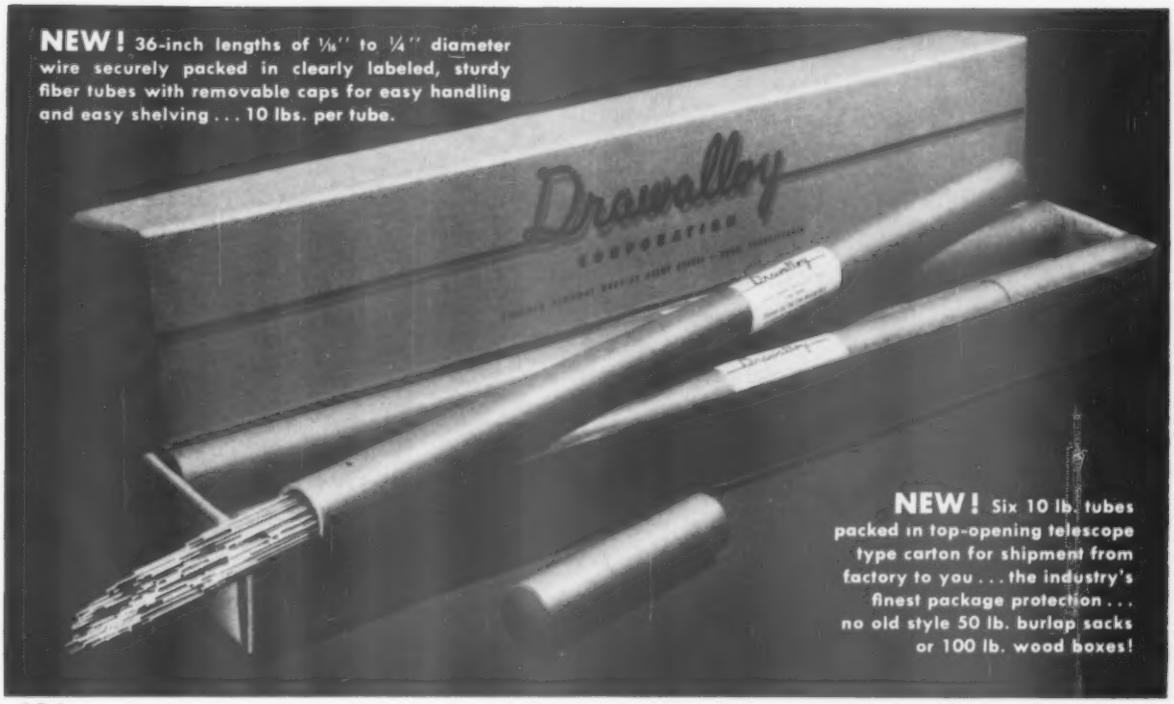
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E. C. "Ed" Rogers, chief metallurgist for the Stoody Co., Whittier, Calif., was the principal speaker at the Tucson Section's organizational meeting which was attended by 68 persons. His topic was "Metallurgy with Relation to Hard Facing." Mr. Rogers presented a part of his lecture using colored slides to illustrate certain important sections of his talk. Mr. Rogers' question-and-answer period invoked much interest and many questions which were well founded.

Charles A. Babbitt, Vice-President of Cal-Metals, Torrance, Calif., and newly elected Vice-President of District 7, AWS, attended this meeting to assist in the formation of this newest AWS Section and he stated that he would return to make an official inspection some time in the early summer after he returns from a business trip to Europe. Mr. Babbitt pointed out that he was surprised and gratified with the interest and enthusiasm created among welders toward the formation of a new section of the AWS in the Tucson area.

Much of the organizational work for this new Section was done under the direction of Don McCowan, past-chairman of the Peoria, Illinois Section, 1951–52. Mr. McCowan pointed out that the Tucson Section can expect support from an area within a 75 mile radius of Tucson, which includes many large copper mines such as American Smelting and Refining properties, Phelps Dodge and Kennecott Copper, as well as many smaller and independent mines. He also indicated that many of the large construction companies and road building companies and many small welding shops will benefit by being members of the Tucson Section.

New Metals

Wichita, Kan.—The regular monthly dinner meeting of the *Wichita* Section was held on February 9th in the Rainbow Room of Coleman Co., Inc. Technical speaker was Glenn A. Fritzlen, Assistant Technical Director, Haynes Stellite Co., Kokomo, Ind. Mr. Fritzlen's discussion on new metals covered recent developments in the field of new alloys and powdered metals.

Coffee speaker was Marion Brandenberger of the Wichita Police Department who gave an excellent talk on the all-important subject of "Safety."

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abstracts of CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington, D. C.

2,626,459—Method of Welding Stainless Steel—Prentiss S. Viles, Baytown, Tex., assignor, by mesne assignments, to Standard Oil Development Co., Elizabeth, N.J., a corporation of Delaware.

This patented welding method relates to the welding of chromium-nickel austenitic stainless steel and the method includes the steps of forming a mixture of hydrocarbon gas between about 95 and 75% by volume and hydrogen sulfide in an amount in the range between about 5 and 25% by volume, igniting the mixture of gas to produce a flame which is applied to adjacent boundaries of the bodies to be welded together, and fusing the adjacent boundaries of the bodies with such ignited gas mixture.

2,627,009—Method of and Apparatus for Welding and Annealing Metal Articles—John H. Corson, Edward A. Suverkrop and Dartrey Lewis, Trenton, N. J., assignors to John A. Roebling's Sons Co., Trenton, N. J., a corporation of New Jersey.

This patent relates to apparatus wherein a pair of welding clamps are provided, and where a pair of annealing clamps are pivotally positioned on a support. The clamps are adapted to grip articles such as a steel wire with the articles disposed in end abutting relation. A welding circuit is provided and includes the welding clamps and the articles to be welded, whereas the annealing circuit provided includes the annealing clamps and the articles. Other means are present in the apparatus for closing the annealing circuit upon movement of the annealing clamps to operative position.

2,628,301—Welding Head—Robert E. Dahl, Hinsdale, Ill., assignor of one-half to Advance Transformer Co., Chicago, Ill., a corporation of Illinois.

This patent relates to a welding head for automatic gas-shielded arc-welding apparatus. The welding head includes a fixed member and a reciprocable member which has a work-engaging shoe thereon, and this reciprocable member is urged in a direction toward the workpiece to press the shoe thereagainst. The reciprocable member also can be moved to raise the shoe from the workpiece when desired and slide means are provided for controlling the movement of such reciprocable member and include a guide slot and a key positioned in such guide slot to prevent rotation of a positioning rod during reciprocal movements of the movable portion of the apparatus.

2,628,302—Arc Welding Apparatus—Joseph M. Tyrner, Brookside, N. J., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York

Tyrner's patent relates to arc spot welding apparatus in which a nonconsumable electrode is gripped in an electrode holder. The electrode holder is slidably positioned and stop means limit the rearward movement of the electrode holder in its support. Manually movable auxiliary means are provided and are operable independently of the advancing and retracting means for the electrode holder for moving the electrode holder forwardly in the support. These auxiliary means move the electrode holder forwardly a distance equal to the desired length of the arc gap whereby when the electrode holder is moved such distance by the auxiliary means, and the end of the electrode holder support is positioned against the surface, the position of the electrode can be adjusted in the holder to contact the surface and produce an arc gap of the desired length when the electrode holder is moved to its fully retracted position.

2,628,325—Apparatus for Inert-Arc Welding—Walter S. Schaefer, East Gadsden, Ala., assignor to Republic Steel Corp., Cleveland, Ohio, a corporation of New Jersey.

An electrode welding torch is disclosed by this patent and it includes an elongate, hollow body, a nozzle cooperating with the body to define a continuous passage

way to receive an electrode, an electrode holder mechanism within the passageway. Other means are present for moving the body lengthwise toward and away from a workpiece to be welded while second means are present and include an electric motor for moving the mechanism within the passageway. Electrical means including arc voltage sensing means are operatively associated with the motor and with an electrode carried by the mechanism for automatically actuating the motor in response to arc voltage fluctuations and moving the mechanism relative to the nozzle and body to maintain arc voltage within predetermined limits.

2,628,530—Ophthalmic Lens Device in Welder's Hood—Ellis L. Rabben, Norfolk, Va.

This patent relates to a welder's helmet that has a vision aperture with a cover and filter glasses thereover. A pair of rectangular corrective lenses are positioned in a rectangular, channeled frame mounted behind the cover and filter glasses. These lenses abute each other along a vertical centerline and have whatever corrective power required for the wearer of the helmet.

2,629,071—Stabilizing Welding Arc—Nelson E. Anderson, Scotch Plains, N. J., assignor to Air Reduction Co., Inc., a corporation of New York.

Anderson's method includes generating from the welding current an alternating synchronizing voltage having peaks corresponding to the voltage reversal intervals of the welding current, and forming pulses timed by certain peaks of the synchronizing voltage. High-frequency oscillations of a substantially single and constant frequency are provided, and such oscillations are timed and controlled by the pulses to form impulses of high-frequency oscillations of substantially constant frequency. These high-frequency impulses are superimposed on the welding arc.

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Supplement to the Welding Journal, April, 1953

The Welding of Thick Plates of High-Strength Aluminum Alloys

Advances in welding methods and techniques and the development of improved filler-metal alloys will enable the design engineer to use strength considerably above those used in the past

by D. C. Martin, M. I. Jacobson and C. B. Voldrich

INTRODUCTION

BATTELLE Memorial Institute has, for the past five years, been conducting an investigation on the welding of thick plates of high-strength aluminum alloys for the Army Ordnance Corps. This paper is a brief summary of the results of this work to show the lines of investigation which have been followed and point out those which proved fruitful.

In 1946, the information available on welding of thick sections of aluminum was quite limited. A survey by Battelle Memorial Institute for the Office of the Chief of Ordnance showed that the welding of both low- and high-strength aluminum alloys had been limited almost entirely to thin sheet and plate.[1] No information was available on the welding of plates or shapes of thick sections. In fact, the survey showed that a number of investigators thought that the high-strength heat-treatable aluminum alloys should not be welded in plate thicknesses over about $^1/_2$ in.

The Army Ordnance Corps saw that there was not enough information available to permit the immediate application of high-strength aluminum alloys to the construction of heavy army equipment. However, they also felt that this material would be very useful in some applications if it could be fabricated, and Battelle was authorized, in 1947, to conduct an investigation on the welding of thick plates of high-strength aluminum alloys.

The objective of the investigation was to determine by what means, if any, high-strength welded joints could be produced in thick plates of the strong aluminum alloys. The solution of the problem required attention to two places where weaknesses occur in such joints: the weld metal itself and the heat-affected zone in the base plate. A high-strength weld metal is required, and the loss of strength at the heat-affected zone must be overcome either by reducing the heat effect of welding, or by postweld heat treatment. The ultimate aim of the investigation was to develop means of making welded joints having joint efficiencies of 80% or better and adequate ductility.

In the past five years, good progress has been made in overcoming both of the deficiencies mentioned above. Filler-metal alloys have been found which produce weldments in 24S and 75S plates having joint efficiencies of 50 to 60% rather than the 30% obtainable with the filler metals in use five years ago. This means that the design stresses for aluminum weldments of thick sections can be doubled, if these filler metals are used.

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When it can be used, heat treatment of welded joints in high-strength aluminum alloys produces very high strengths. In the case of one aluminum alloy (61S), joint efficiencies of 100% are obtainable by postweld heat treatment. In addition, the weakness caused by heat effect in the base plate can be partially overcome by using a new welding process which is now available commercially.

During the course of this investigation, contributions to its progress have been made by many members of the Battelle Institute staff. Among those who have been more directly concerned are: L. K. Birinyi, A. R. Meyer, J. L. Dethloff, C. B. Disbennett, C. M. Craighead, R. D. Williams, C. E. Sims and Dr. S. L. Hoyt. In addition, acknowledgment is due A. L. Jamieson, F. W. Hussey and E. R. Rechel of the Pitman-Dunn Laboratory at Frankford Arsenal and E. L. Hollady, of the Office of the Chief of Ordnance, for their assistance throughout the course of the investigation.

PLATE MATERIALS

There are several commercially available aluminum alloys which have high strengths. From these, three were chosen to be used in this investigation. The alloy known commercially as 61S was chosen because it was a widely used medium-strength structural alloy. The Alloys 24S and 75S were chosen because they were widely used high-strength alloys.

For most of the work done during this investigation, the plates used were in the heat-treated condition that produced the highest strength. In these conditions, the minimum ultimate strengths of thick plates are as follows:[2] 61S, 42,000 psi; 24S, 60,000 psi and, 75S, 77,000 psi.

WELDING METHODS

At the start of this investigation, four methods of welding heavy aluminum sections were considered. These were:

1. Gas welding, using an oxy-acetylene torch.
2. Metal-arc welding, using a flux-coated electrode.
3. Carbon-arc welding, using an uncoated filler-metal wire and a powder flux applied to the weld during welding.
4. Inert-gas-shielded tungsten-arc welding, using an uncoated filler-metal wire.

Gas welding was not used because it introduces a large amount of heat into the plate and produces a wide heat-affected zone and low-efficiency joints.

A large number of tests were made using the metal-arc process, the carbon-arc process, and the inert-gas-shielded tungsten-arc process (hereafter called the argon-arc process), to determine which of these processes produced the soundest welds and, in general, was the most satisfactory for welding thick plates of high-strength aluminum. Welds made by the metal-arc process were not considered acceptable because they contained sufficient porosity to be detrimental to weld ductility. Although the carbon-arc process produced sound welds, it was difficult to use because the powdered flux spread over the weld area before and during welding and kept the operator from seeing the weld pool. In addition, this flux was apt to be trapped in the weld and produce a poor joint. Flux entrapment was also a problem with the metal-arc process. Considering such factors as ease of training welding operators, ease of welding, visibility of the work, cleaning of the finished weld and quality of the weld metal, the argon-arc process proved to be the most satisfactory for welding thick aluminum plates.

During the course of this investigation, a fifth process was introduced commercially which is well suited to the welding of thick aluminum plates. This process consists of continuously feeding a bare filler metal, in wire form, through a gas nozzle. The nozzle maintains a shield of inert gas around the arc and weld area. The bare filler-metal wire carries the welding current, and the arc is maintained between the end of the wire and the work. Throughout this report, this process will be called the inert-gas-shielded consumable-electrode process.

The inert-gas-shielded consumable-electrode process is about five times as fast as other fusion welding processes which can be used for aluminum. It permits continuous deposition of filler metals at high rates and, like the argon-arc process, does not require the use of flux. Another advantage is the deep penetration obtained, which makes it possible to produce square-butt welds in plates up to 1 in. thick. A major advantage is that no preheat is required when the inert-gas-shielded consumable-electrode process is used, which means that there is less heat effect in the base plate being welded and that the heat-affected zone next to the weld is stronger than for the other welding methods.

At present, the inert-gas-shielded consumable-electrode process has one disadvantage. Welds produced with it in thick plates may contain some porosity. A study of this porosity indicates that it is due to hydrogen. Although careful control of joint preparation and welding conditions can substantially reduce weld-metal porosity, it is very difficult, if not impossible, to eliminate it entirely. At present, it is not certain what effect the porosity has on strength and ductility. It may be that the amounts present have an insignificant effect, but without definite knowledge it must be suspected that porosity is deleterious.

PROPERTIES OF CONVENTIONALLY WELDED JOINTS

As mentioned previously, there was very little information available at the start of this investigation on the properties of welded joints in thick plates of strong aluminum alloys. To acquire background material and to develop the needed information, a test program was carried out to determine the strength properties of

welded joints in 61S, 24S and 75S plate using conventional filler-metal alloys.

The filler-metal alloys used in this part of the investigation were the 5% silicon alloy, 43S; a 10% silicon-4% copper alloy, 716; and rods of the 61S, 24S and 75S alloys. The 43S alloy was chosen because, at the time this investigation was started, it was the filler metal most commonly used for welding high-strength aluminum parts. The 61S, 24S and 75S filler metals were used because, in an investigation of this type, it is generally common practice to determine whether a base metal can be welded with itself. Although employed principally as a brazing material, 716 alloy was used for making experimental welds because it was known to have fairly high strength and was available commercially.

In general, all of the filler metals except 61S produced sound welds of good appearance. Welds made with 61S filler metal invariably cracked, although changes in preheat and other welding conditions were tried to prevent cracking. A large number of tests have shown that this cracking is a hot-short characteristic inherent in 61S and similar aluminum-magnesium-silicon alloys,[3] and that it is not noticeably affected by joint design or welding procedure.

Consideration of the information obtained from transverse tension tests and shown in Fig. 1 indicated two things. The first was that the as-welded joint efficiencies of welds made with conventional filler metals were lower than desired. In the case of 61S base plate and 716 filler metal, the low joint efficiency was caused by the weak heat-affected zone next to the weld. Transverse tensile specimens cut from 61S weldments made with 716 filler metal usually broke through this heat-affected zone. The joint efficiencies in the 61S weldments made with 43S filler metal and in 24S and 75S weldments were low, because the strength of the filler metals used was considerably less than that of the base plate.

In addition to the argon-arc welds made with conventional filler metals, welds were also made in high-strength base plates using the inert-gas-shielded consumable-electrode process and 43S filler metal. The results of transverse tension tests on as-welded specimens cut from these joints were from 10 to 20% higher in joint efficiency than those obtained from welds made with the argon-arc process. This increase was probably due to the fact that there is less dilution of the weld metal by the base metal than in the argon-arc process. Also, in the case of 61S, the heat-affected zone was narrower and stronger than that produced in argon-arc welds.

The welds made with the inert-gas-shielded consumable-electrode process had less ductility than those made with the argon-arc process. This low ductility probably resulted from the porosity present in the welds made with the inert-gas-shielded consumable-electrode process and the stronger heat-affected zones in these welds.

The results of all of the tests made with the "conventional" filler metals showed that both the heat-affected zone and the weld metal could be points of weakness in weldments in thick aluminum plates. Consequently, it was necessary to investigate means of developing higher strengths in both weld and heat-affected zone.

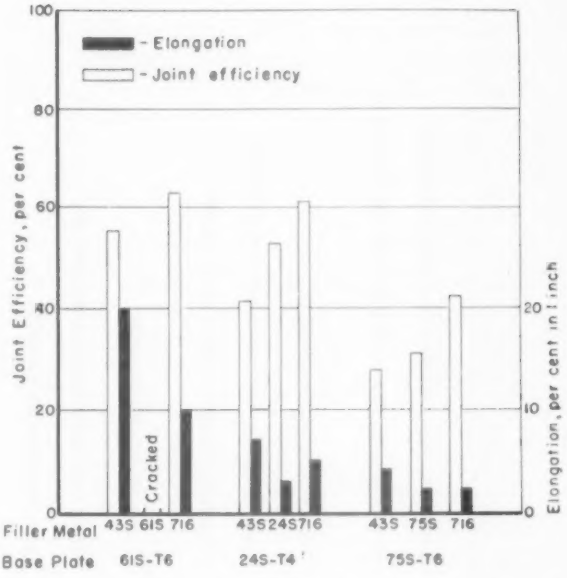

Fig. 1 As-welded joint efficiencies and elongations of tungsten-arc weldments made with conventional filler metals

DEVELOPMENT OF HIGHER EFFICIENCY JOINTS

The first attack was made on both the weld-metal and heat-affected-zone problems by determining the effects of postwelding heat treatments on the strength of weldments in the various base plates.

Effect of Heat Treatment

The heat treatments used to obtain fully heat-treated specimens were those employed to produce the maximum strength in each of the three types of base plates. Thus, welds deposited in 61S, 24S and 75S base plates each received different postweld heat treatments. In addition to full heat treatments, postweld aging heat treatments were also used. It was thought that possibly the rapid quench which occurs in a weld had put the heat-affected zone and possibly the weld metal in a solution-treated condition. If this were true, the aging treatment would cause age hardening and increase the strength of both the heat-affected zone and the weld metal.

The results of transverse tension tests of both aged and fully heat-treated specimens cut from weldments in the three types of base plate are given in Fig. 2. The as-welded values are included for comparison. The

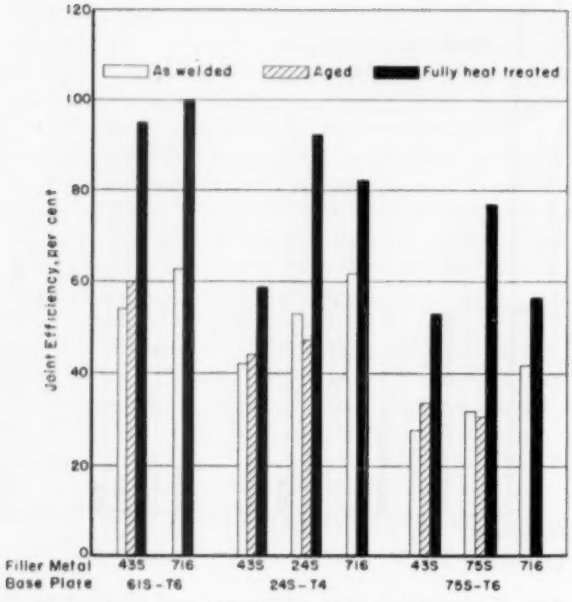

Fig. 2 Comparison of joint efficiencies of as-welded and heat-treated joints welded with conventional filler metals

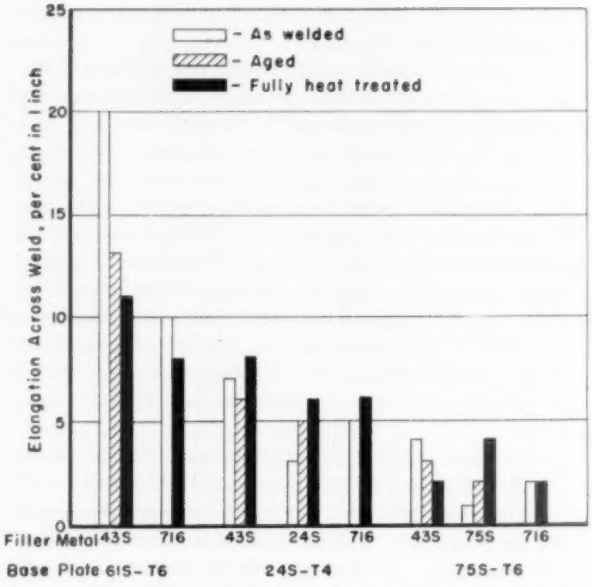

Fig. 3 Comparison of free-bend elongations of as-welded and heat-treated joints welded with conventional filler metals

bend ductilities of the welded specimens are shown in Fig. 3.

It is evident from Fig. 2 that aging had little effect on the joint efficiencies of the weldments. In some cases, aging produced a slight change in properties, but the changes were not very significant.

The full heat treatments produced an improvement in the joint efficiency of all the weldments. In some cases, these improvements were very large. For instance, in weldments made with 61S plate and 71S filler metal, the joint efficiency increased from about 50 to 100%. In the cases of 24S and 75S weldments, joint efficiencies as high as 90% were obtained. Unfortunately, the bend ductilities of the weldments were not affected by the full heat treatment, and, therefore, were still low in 24S and 75S weldments.

The results of the tests of the heat-treated weldments showed that considerable increases in strengths of weldments in high-strength aluminum plates could be obtained by postweld heat treating. For designs that lend themselves to heat treatment, this method of producing high joint efficiencies can be used successfully. However, the heat treatment of large aluminum structures is a difficult task. At the temperatures used, aluminum is very weak, and elaborate supporting jigs would be required for structures of any size. Good quenching is also required to achieve the best results and this is difficult to obtain in large structures. Consequently, attention was turned to obtaining higher strength weldments by development of filler-metal alloys which would produce higher strength weld metals in the as-deposited condition. Such alloys would make it possible to obtain higher joint efficiencies with 24S and 75S plates in the as-welded condition than was possible with the "conventional" filler metals.

Development of High-Strength Filler Metals

A filler-metal development program was undertaken in which a large number of filler metals were surveyed to determine whether one or more could be found which would give high joint efficiencies and reasonable ductilities in the as-welded condition. The 55 filler metals studied in this part of the investigation fell into three general classes.

The first class contained alloys of aluminum with silicon and copper. These alloys were suggested by the good results obtained with 71S filler metal in previous tests, and by the fact that several alloys of this type were used to produce high-strength castings.

The second class contained alloys of aluminum, magnesium and zinc. These were based on a casting alloy produced by the Frontier Bronze Co. and designated by them as 40E. This alloy produces castings in which age hardening from the as-cast condition results in high strength combined with appreciable ductility. The Cornell Aeronautical Laboratories have tried some of the aluminum-magnesium-zinc alloys as filler materials for welding light-gage high-strength sheet aluminum. They reported that this type filler metal gave excellent weld joint efficiencies in thin sheet.

The third class of filler metals investigated was aluminum alloys containing magnesium as the principal alloying element. These alloys were investigated because they have high strengths in the as-cast condition and, in addition, have excellent ductility. A second reason for investigating these alloys was that, in Europe, wrought aluminum-magnesium alloys are used as structural materials and are welded with filler materials which have the same composition as the base plate. British sources have reported excellent joint efficiencies

for weldments made with the aluminum-magnesium base plate and aluminum-magnesium filler metals.[4, 5]

In this portion of the investigation, the test procedure followed was somewhat different from that used when conventional filler metals were studied. Preliminary tests were made with most of the experimental filler metals by depositing them between copper dams. This procedure was used to obtain weld metal which had not picked up additional alloying elements from and had not been diluted by the base plate. All-weld-metal specimens were cut from these copper-dam deposits and tested in tension. The results of these tests were used as a basis for comparing the results of tests on all-weld-metal specimens cut from deposits in 618, 248 and 758 base plate. If, through these preliminary tests, the filler metals were found to have attractive strength properties, they were used to prepare weldments for transverse tension tests.

Table 1 gives the compositions of all filler metals tested.

Aluminum-Silicon-Copper Filler Metals

In this group, two experimental filler metals were used to fill the composition gap which existed between 438 and 716 filler metal. Both filler metals produced

Table 1—Nominal Chemical Composition of Aluminum Filler-Metal Alloys

Alloy designation	*Composition, %*								
	Cu	*Si*	*Mg*	*Zn*	*Cr*	*Ti*	*Mn*	*Other*	*Al*
Conventional alloys									
28	...	...	...	...	...	...	...	...	99+
38	...	...	...	...	...	...	1.2	...	Rem
248	4.5	...	1.5	...	...	...	...	...	Rem
438	...	5.0	...	...	...	...	...	...	Rem
618	0.25	0.6	1.0	...	0.25	...	...	...	Rem
758	1.6	...	2.5	5.6	0.3	...	...	...	Rem
Al-Cu-Si alloys									
716	5	10	...	...	...	...	...	...	Rem
VF-3	2.5	5.0	...	...	...	...	...	...	Rem
VF-5	3.5	8.5	...	...	0.25	...	...	...	Rem
VF-9	2.5	5.0	...	...	0.25	...	...	...	Rem
Al-Mg-Zn alloys									
VF-1	...	...	0.5	5.0	0.8	0.2	...	0.4 Ce	Rem
VF-2	...	...	0.5	5.0	0.8	0.2	...	...	Rem
VF-4	...	14.0	0.5	5.0	0.5	0.2	...	...	Rem
VF-10	...	...	0.5	5.5	0.5	0.2	...	...	Rem
VF-11	...	...	0.5	5.5	0.5	0.2	...	0.04 B	Rem
VF-12	...	...	0.5	5.5	0.5	0.2	...	0.3 Ca	Rem
VF-13	...	...	0.5	5.5	...	0.2	0.5	...	Rem
VF-14	...	...	0.5	5.5	0.25	0.2	0.25	...	Rem
VF-15	...	...	0.75	4.5	0.5	0.2	...	...	Rem
VF-16	...	...	0.25	7.0	0.5	0.2	...	...	Rem
VF-25	1.0	...	0.5	5.5	0.5	0.2	...	...	Rem
VF-26	2.0	...	0.5	5.5	0.5	0.2	...	...	Rem
VF-27	1.0	...	0.75	4.5	0.5	0.2	...	...	Rem
VF-28	...	...	0.5	5.5	0.5	0.2	...	2.5 Ni	Rem
Al-Mg alloys									
VF-8	...	...	10.0	...	...	...	...	0.005 B	Rem
VF-17	...	...	10.0	...	...	...	...	0.2 Be	Rem
VF-18	...	...	5.25	...	0.1	...	0.1	...	Rem
VF-19	...	...	7.0	...	...	...	0.2	...	Rem
VF-20	...	...	8.0	...	...	...	...	...	Rem
VF-21	...	...	9.0	...	...	...	0.2	...	Rem
VF-22	...	...	11.0	...	...	...	...	0.005 B	Rem
VF-23	...	...	12.0	...	...	...	...	0.2 Be	Rem
VF-24	...	...	15.0	...	...	...	...	...	Rem
VF-29	...	...	8.0	...	...	...	...	0.3 Ca	Rem
VF-30	...	...	10.0	...	...	...	...	0.3 Ca	Rem
VF-32	...	0.5	8.0	...	...	0.2	...	...	Rem
VF-36	...	...	8.0	...	...	...	...	0.5 Zr	Rem
VF-37	...	...	8.0	...	...	...	...	0.2 Ce	Rem
VF-39	...	...	8.0	...	...	...	...	0.6 Ca	Rem
VF-40	...	0.5	8.0	...	...	0.2	0.5	...	Rem
VF-41	...	1.0	8.0	...	...	0.2	...	...	Rem
VF-42	...	2.0	8.0	...	...	0.2	...	...	Rem
VF-43	...	3.0	8.0	...	...	0.2	...	...	Rem
VF-44	...	0.5	10.0	...	...	0.2	...	...	Rem
VF-45	...	2.0	10.0	...	...	0.2	...	...	Rem
VF-46	...	4.0	10.0	...	...	0.2	...	...	Rem
VF-47	...	0.5	12.0	...	...	0.2	...	...	Rem
VF-48	...	2.5	12.0	...	...	0.2	...	...	Rem
VF-49	...	5.0	12.0	...	...	0.2	...	...	Rem
VF-50	...	0.5	8.0	...	...	0.4	...	...	Rem
VF-51	...	0.5	8.0	...	...	0.8	...	...	Rem
VF-52	...	0.5	8.0	...	...	...	...	0.5 Zr	Rem
VF-53	...	1.0	8.0	...	...	...	...	0.5 Zr	Rem
VF-54	...	...	8.0	...	...	...	...	1.0 Zr	Rem
VF-55	...	1.5	8.0	...	...	...	...	0.5 Zr	Rem

Table 2—Comparison of As-Welded Strength Properties of Various Filler Metals Deposited in 61S, 24S and 75S Base Plate

Filler metal	61S base plate			24S base plate			75S base plate		
	Ultimate tensile strength, psi	Yield strength,* psi	Elongation in 2 in., %	Ultimate tensile strength, psi	Yield strength,* psi	Elongation in 2 in., %	Ultimate tensile strength, psi	Yield strength,* psi	Elongation in 2 in., %
43S	24,000	10,500	12	30,000	13,500	10	26,000	12,500	6
71S	41,000	15,000	7	44,000	20,000	7	41,000	19,000	5
8% Mg	39,360	21,000	14	37,000	22,200	8	28,000	22,400	4
9–11% Mg	43,600	24,100	10	40,900	25,500	6	37,300	25,300	5
Modified Al-Mg	46,500	21,800	13	39,500	22,900	6	45,300	23,300	4
Frontier 40E†	32,000	22,500	10	...	...	...	...	...	...

* 0.2% offset.
† Aged 90 days.

weld metals which had higher strengths than 43S, but neither had strengths as high as those produced in 71S deposits. In addition, the ductilities of the deposits made with the experimental alloys were lower than those made with 43S. Since the as-welded and heat-treated strengths of welds made with the experimental alloys were lower than 71S, no further work was done with them.

Aluminum-Magnesium-Zinc Filler Metals

The first aluminum-magnesium-zinc filler metal used was an alloy containing 0.5% magnesium and 5% zinc. Tests of this alloy showed that satisfactory weld deposits could be obtained between copper dams and in 61S plate. However, when welds were made with the aluminum-magnesium-zinc alloy in 24S or 75S base plates, the welds invariably cracked. Strength tests of the deposits made between copper dams and in 61S plate showed that the welds had fairly good as-deposited strength and very good ductility. Aging tests of deposits in copper dams and 61S plates showed that, after 90 days at room temperature, welds made with the aluminum-magnesium-zinc alloy had high ultimate and yield strengths and still retained good ductility. Ultimate strengths of 35,000 to 40,000 psi and yield strengths of 25,000 psi, with elongations of 15% or better in 2 in., were obtained in the all-weld-metal specimens aged at room temperature.

Because of the results obtained from copper-dam deposits and deposits in 61S plate, an extensive program was carried out to try to reduce the cracking tendencies of the aluminum-magnesium-zinc alloys when used as filler metals in 24S and 75S base plates. This program involved production and testing of a number of aluminum-magnesium-zinc filler metals with varying compositions and with additional alloying elements added. Changes were made in the magnesium to zinc ratio; grain-refining additions were made to try to reduce the continuity of eutectic envelopes around the grains; additions were made to increase the amount of eutectic present in the structure; and additions were made to try to tie up copper picked up by the weld metal from the base plate in the hope that cracking tendencies of the weld metal would be eliminated. None of the modifications tried was successful. In addition, the presence of other alloying elements lowered the strength of the welds and adversely affected the natural-aging characteristics of the alloy.

A great deal of effort was expended trying to develop a useful modification of the aluminum-magnesium-zinc filler metal. However, work on these alloys was stopped because of the favorable results obtained with aluminum-magnesium filler metals.

Aluminum-Magnesium Filler-Metal Alloys

The aluminum-magnesium filler-metal alloys used in this investigation contained from 5 to 15% magnesium.* According to the available information on casting alloys,[2] 8 to 10% magnesium appeared to be an optimum figure, but the magnesium content was extended on both sides of this optimum to cover the range that might be expected to give good results.

These tests with the aluminum-magnesium filler-metal alloys showed that alloys containing from 8 to 11% magnesium had the best combination of strength and ductility. In the as-welded condition, these alloys produced higher yield and ultimate strengths than had been obtained previously with any other filler metal. In addition to the high ultimate and yield strengths, the welds produced with aluminum-magnesium filler metals had adequate ductility. A comparison of the strengths of welds made with the aluminum-magnesium filler metals and with other filler metals is given in Table 2.

Transverse tension tests were made on joints in 61S, 24S, and 75S plates welded with aluminum-magnesium alloys containing 8 to 11% magnesium. The results of the transverse tension tests were not so good as the all-weld-metal tests had indicated they should be. In 61S base plate, the strength of the transverse-tension specimen was dictated by the heat-affected zone, since all fractures occurred in this part of the specimen. However, in 24S and 75S plates, the joint efficiencies were considerably lower than expected. It was believed that these low joint efficiencies were the result of dilution from the base plate, and a series of tests was made using the inert-gas-shielded consumable-electrode welding process to determine if reduction of dilution from the base plate would increase the joint efficiencies of the

* Detailed information on the properties of welds made with these alloys have been reported in Reference 6.

welds. At the time these tests were made, there was no small-diameter 8 to 11% magnesium-alloy wire available for inert-gas-shielded consumable-electrode welding. Because of the time required to obtain small-diameter wire, some tests were made with the commercially available wire containing 5.25% magnesium. Figure 4 shows the results of transverse-tension tests on welds made with this 5.25% magnesium wire, and compares these with the results of argon-arc welds made with 8 to 12% magnesium filler wire. This figure shows that, with the inert-gas-shielded consumable-electrode process, joint efficiencies of the welds made with the 5% magnesium alloy were as high as those obtained with the filler-metal alloys containing about twice as much magnesium. This indicates that, if the higher magnesium content wires were used with the inert-gas-shielded consumable-electrode process, the joint efficiencies should be close to those which would be predicted from the all-weld-metal tension tests.

Some tests have been made in an effort to increase the strength of the binary aluminum-magnesium-alloy weld deposits. An aluminum-8% magnesium alloy was modified with 0.5% silicon and 0.2% titanium. Preliminary tests made with all-weld-metal specimens showed that the ultimate strengths of the deposits were higher by 7000 psi in 61S, 2500 psi in 24S and 17,000 psi in 75S as compared with the ultimate strengths of the aluminum-8% magnesium alloy deposited in the same plate. The yield strength also increased slightly, and there was no decrease in ductility. A number of tests of modifications of the aluminum-magnesium-silicon-titanium filler metal have been made and these have indicated that the original composition was the best for use in 24S and 75S plate.

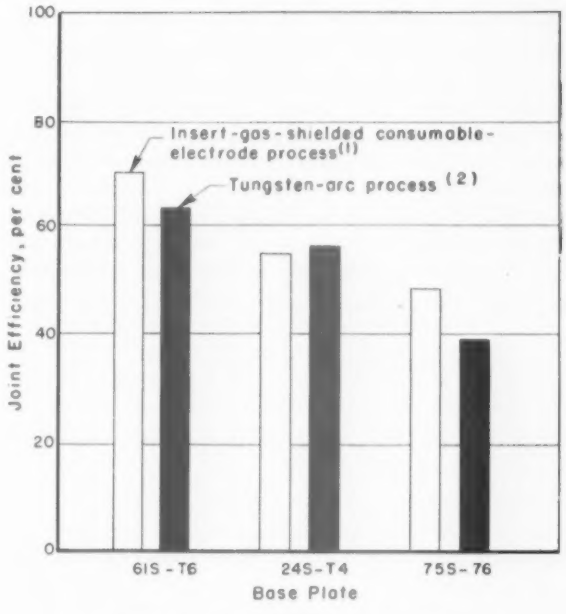

Fig. 4 Comparison of joint efficiencies of welds made with the inert-gas-shielded consumable-electrode process and the tungsten-arc process using aluminum-magnesium filler metals

Discussion of Results

Most of the aluminum-alloy systems which appear to hold promise for filler metals have been investigated. Out of this has come a better knowledge of the strengths available in weldments in thick aluminum plates, while a considerable increase in strength over what could be obtained at the time the investigation started has been achieved. The aluminum-silicon-copper alloy 716 can be used effectively when heat treatment is possible. With this alloy and postweld heat treatments, increases of 50 to 100% in joint strength are obtained over what was available five years ago.

When postweld heat treatments cannot be used, the aluminum-magnesium alloy containing 8 to 10% magnesium and modified with silicon and titanium can be used. In 24S and 75S plates, as-welded joint efficiencies of 60% are possible. This is almost double the corresponding joint efficiencies obtainable in weldments of these base-plate alloys five years ago. Figure 5 compares the strengths of weldments made as suggested with base-plate strength. Values for weldments made with 43S are included to show what was available five years ago.

The present outlook is that the maximum joint ef-

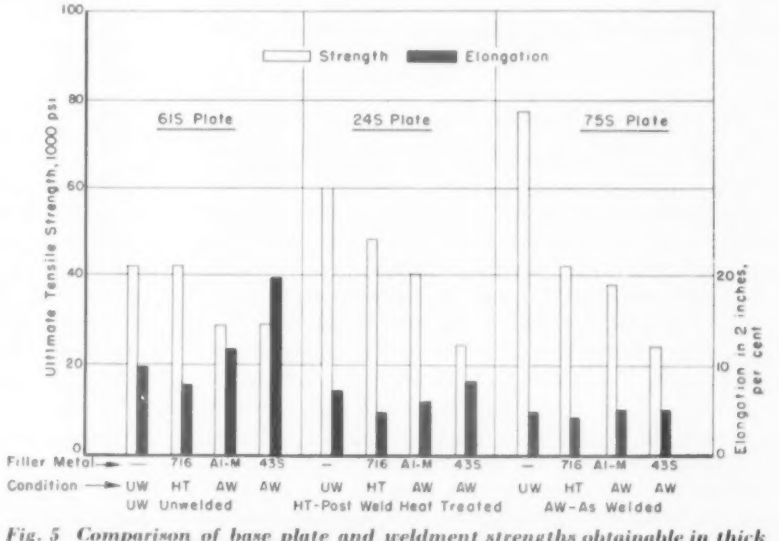

Fig. 5 Comparison of base plate and weldment strengths obtainable in thick plates of three types of high-strength aluminum alloys. The data for 43S show the weldment strengths obtainable when this investigation started

ficiencies for weldments in thick plates of 24S and 75S have been obtained. No aluminum-alloy systems are known which will produce ductile as-welded joints of higher strengths than those now available. In addition, no solution has been found for the problem of the heat-affected zone other than postweld heat treatment of the weldment.

Unless some presently undeveloped aluminum-alloy system appears in the future, the highest joint efficiencies obtainable in weldments in thick aluminum will be:

Plate alloy	Joint efficiency, %: As-welded	Joint efficiency, %: Heat treated	Base-plate strength, psi
61S	70–80	100	42,000
24S	60–70	80–90	60,000
75S	50–60	50–60	77,000

One possibility of producing high joint efficiencies without heat treatment is to develop an alloy base plate which is not affected by welding as are the present high-strength aluminum alloys. Such an alloy probably would have lower strengths than 24S or 75S, perhaps of the same order or somewhat higher than 61S. In Great Britian and continental Europe, the aluminum-magnesium alloys have been used for some time as structural material. An American alloy which has the desired characteristics is the aluminum—5% magnesium alloy known as 56S. However, only recently has this become available in forms other than wire. Some of these alloys have strengths as high as 40,000 to 45,000 psi in the annealed condition.[4, 5] Alloys such as these can be welded with aluminum-magnesium filler metals and 100% joint efficiencies will be obtained. The aluminum-magnesium alloys have one disadvantage, they are susceptible to stress-corrosion attack when high magnesium contents (over about 5%) are used. However, this might not be a problem in many uses.

Another possibility of producing higher joint efficiencies is to replace fusion welding methods by other welding methods. One nonfusion welding method, which has been investigated, is discussed briefly in the next section.

COLD WELDING OF ALUMINUM

As mentioned previously, the heat-affected zone of a weld can be the weakest zone in the weld. This has been noted throughout the previous sections in the case of 61S base plates welded with the higher strength filler metals. This weak heat-affected zone can be removed by heat treating, but quite often this is not possible in large structures. For a number of years, a process known as cold welding has been used in the joining of thin sheets of aluminum. In this process, no heat is used; the weld is achieved by pressing the sheets together between dies which produce a large amount of plastic flow. Welds of reasonable strength in thin sheets can be obtained using this method. A number of tests were made to see if this method of welding could be extended to thick plates but without success. The primary reason for failure was the lack of sufficient information about the fundamental aspects of cold welding. There is at present some work being done on the fundamentals of this joining process. In the future, the results of this work may make it possible to cold weld thick sections of aluminum at room temperature.

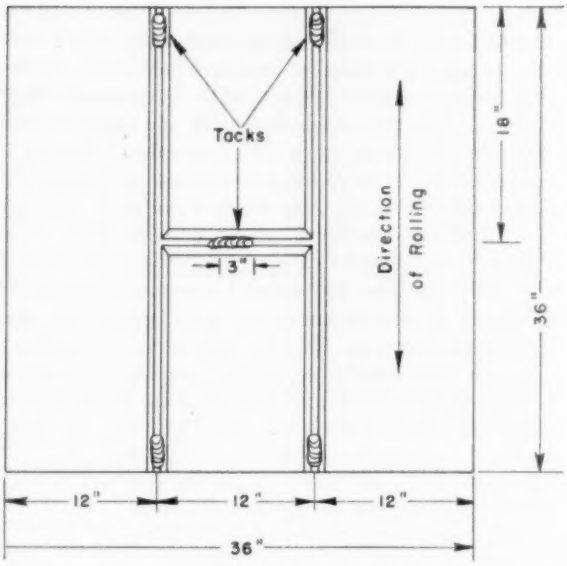

Fig. 6 Location and dimensions of the four plates used in making a welded H-plate assembly

If it proves impossible to make useful joints in thick plates at room temperature, it may be possible to make them at 500 to 800 F. Some work has been done on solid-phase bonding of aluminum at these temperatures, and the technique has been used commercially on thin sheets. If welding is done fast enough, the temperatures used may not have too great an effect on the properties of the high-strength aluminum alloys.

WELDING RESTRAINED JOINTS

One of the properties of an aluminum weldment in which the Ordnance Corps is interested is its ballistic behavior. In a part of this investigation, a number of ballistic test specimens were made for Frankford Arsenal. The specimens were standard H-plates and were made with 75S and 24S aluminum alloys. Figure 6 shows the size and arrangement of this type of ballistic test specimen. Most of the welding on these plates was done with the aluminum—8% magnesium filler metal. The normal procedure for welding this type of plate is to weld the leg welds first, and then weld the cross weld. Since the cross weld is not made until last, it is under conditions of very severe restraint. Figure 7 shows an H-plate in position for welding.

H-plates were made in $^3/_4$-in. 24S and 75S plates with little trouble using the argon-arc welding process. Some cracking occurred when the cross weld was made, particularly in the root pass of the double-vee joint used. However, by using fairly thick root passes (about $^1/_4$ in. thick) and alternating from one side of

Fig. 7 H-plate made of 3/4-in. 24 S-T plate after welding leg welds. Cross weld not finished

the joint to the other on subsequent passes, it was possible to make sound test specimens.

The plan of the investigation was to follow the 3/4-in.-thick plates with 1 1/2-in. H-plates. However, a great deal of trouble was encountered in trying to fabricate the 1 1/2-in.-thick H-plates. No H-plates in 1 1/2 in.-thick aluminum were produced with sound cross welds when the cross weld was welded last.

The type of joint used in the 1 1/2-in. H-plates is shown in Fig. 8. The procedure used to try to weld these cross welds was to put a root pass and either one or two more passes on one side of the weld. The plate was then turned over, and three passes were put in on the second side. The plate was then turned over again and welding was finished on the first side.

The cross welds invariably cracked during welding. Generally, the first pass appeared to be sound and on some subsequent pass the weld would crack. A considerable amount of time was spent trying to devise a technique to overcome the cracking. Weld passes of different thicknesses, different pass sequences, backstepping of welds, welding in different positions, and different preheats were tried. None of these things was successful in producing cross welds that were free from cracking.

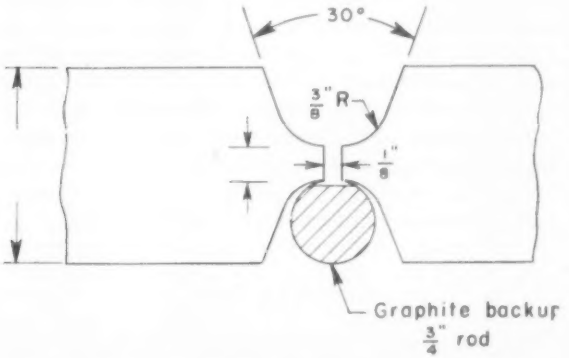

Fig. 8 Double-U groove-joint design for H-plate made with 1 1/2-in. plates

When it was found impossible to produce sound cross welds using the aluminum-magnesium filler metal, it was thought that perhaps the fault lay with the filler metal. Consequently, a number of H-plates were welded in which 43S was used as the filler metal. This had no effect on the cracking of the cross weld.

Other plates were welded using the inert-gas-shielded consumable-electrode process and 43S filler metal. With this process, it was possible to make the cross weld in two passes, one from each side. However, these welds also cracked.

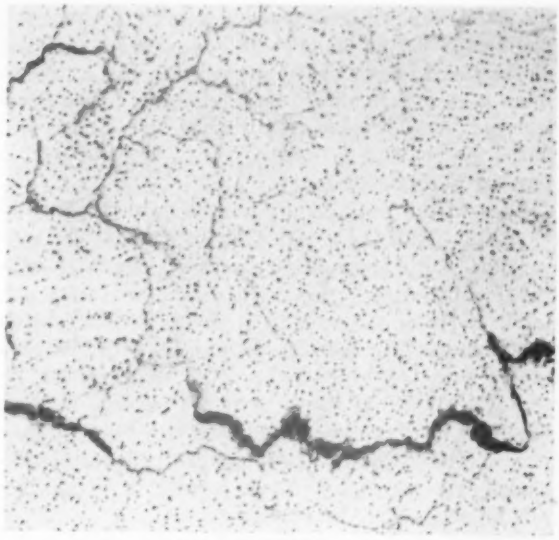

Fig. 9 Example of microcracks in the weld metal of a 1 1/2-in.-thick 75S H-plate welded with aluminum-8% magnesium filler metal

The obvious cause of the cracking is, of course, the high restraint on the cross weld during welding. However, it appears that the copper pickup from the base metal by the weld is also a contributing factor. Figure 9 shows the structure in the root pass of a weld in a 1 1/2-in.-thick plate. The crack which can be seen in this photomicrograph follows a line of intergranular precipitate and may be either a crack or a shrinkage cavity. It appears that the weld deposit may contain a number of very small cracks. One or more of these cracks may propagate when stresses in the weld become high enough during cooling to cause failure of the welds.[7, 8]

Sound H-plate specimens have been produced in 24S and 75S base plates by welding the cross weld first. Even when this is done, considerable care must be taken in finishing the leg welds to prevent cracking.

This difficulty suggests that highly restrained joints

should be avoided in weldments in the high-strength aluminum alloys. This is particularly true where thicknesses over $^3/_4$ in. are encountered. Such a limitation can be a serious hindrance to the use of aluminum. It is hoped that future developments will point out a solution to the problem.

HYDROGEN IN ALUMINUM

The inert-gas-shielded consumable-electrode process will probably become in the near future the preferred method for welding aluminum structures. As mentioned previously, one of the deficiencies of this welding process has been the porosity produced in the weld. Over the past few years, considerable effort has been expended by various organizations to develop a cure for this deficiency. This effort has produced partial but not complete success.

It is suspected, with good reason, that hydrogen is the cause of porosity in aluminum welds. There is a drastic drop in the solubility of hydrogen in aluminum as the metal freezes.[9] Hydrogen which has gone into solution in molten aluminum precipitates during freezing, and, in welds made at high speed, the bubbles produced are not able to escape. These bubbles are the porosity in the solidified weld.

Most of the work on the prevention of porosity in aluminum welds made with the inert-gas-shielded consumable-electrode process has been concerned with treating the wire to remove hydrogen-producing materials (grease, water, etc.) from its surface. Little attention has been given to the possibility of hydrogen occluded in the wire or the plate being welded, although a number of people have believed that occluded hydrogen might contribute to weld porosity. In fact, it has been indicated by work done in England that occluded hydrogen is the cause of porosity in welds in aluminum-magnesium alloys.[10]

Table 3 gives the results of a number of hydrogen analyses made on various aluminum alloys. The amounts of hydrogen present on the surface of all of the alloys analyzed were approximately the same per unit surface area. Variations in total surface-hydrogen values in the table are due to variations in sample size. Surface hydrogen amounted to about 0.0038 ml per square centimeter of surface area. The amount of occluded hydrogen varied from less than 0.1 ml to about 0.7 ml per 100 grams of aluminum. At the melting point of aluminum, these quantities represent from 2 to 8 per cent by volume. Such amounts of occluded hydrogen could make an appreciable contribution to porosity in welds in the various aluminum alloys. A moderately porous weld may contain from 10 to 15% by volume as porosity. So far as the inert-gas-shielded consumable-electrode process is concerned, the major source of hydrogen causing porosity is probably the water absorbed on the surface of the wire as hydrated aluminum oxide. The reason for this is that small-diameter wires are used in this process with large surface-to-volume ratios. However, the results of the analysis of aluminum for occluded hydrogen indicate that some wrought-aluminum products may contain sufficient hydrogen to cause weld porosity, even when the wire surfaces are perfectly dry.

Table 3—Distribution of Hydrogen in Wrought Aluminum Alloys*

Alloy	*Total hydrogen (as-received), ml per 100 g*	*Total internal hydrogen, ml per 100 g*	*Total external hydrogen, ml per 100 g†*
2S	0.5	<0.1	0.5
24S	0.8	0.3	0.5
43S	1.0	0.7	0.3
61S	0.8	0.2	0.6
75S	0.7	0.4	0.3
Al-5% Mg	0.7	0.4	0.3

* Precision of values is ±0.1 cc H_2 per 100 g of sample. This table reproduced from data in unpublished paper by M. W. Mallett and C. B. Griffith of Battelle Memorial Institute.

† These values differ because of variation in sample size. All samples had approximately 0.0038 ml. of hydrogen per square centimeter of surface area.

Over the past few years, some other evidence of the influence of occluded hydrogen on weld porosity has been noticed in welding investigations done at Battelle Institute. One striking instance occurred when welds were made between two pieces of $^1/_2$-in. thick 61S plate. The operator remarked that during welding he noticed the escape of bubbles from the side of the weld. When the weld was radiographed, it was found that there was a line of porosity associated with the fusion zone on one side of the weld. Apparently, one of the plates used contained considerably more occluded hydrogen than did the other, and this caused the segregated porosity found in the weld which was noticed by the operator. Unfortunately, no analytical method was available at the time of these observations for determining the amounts of hydrogen in the two plates.

Another example of the possible effect of occluded hydrogen has been observed when welding with the inert-gas-shielded consumable-electrode process in a controlled-atmosphere chamber. For these tests, the wire and the plate were cleaned and placed in the chamber which was evacuated to about 20-micron pressure and then filled with dry helium. Both the wires and the plates were mechanically cleaned inside the controlled-atmosphere chamber, and welding was carried on without exposing them to air. Welds made on 3S plate with 2S wire contained no porosity which could be seen in a radiograph. However, welds on 61S plate with 43S wire contained considerable porosity, although they were not so porous as welds made in the open. These observations indicate that, although the wire surface is treated in a manner to exclude absorbed water, occluded hydrogen can cause weld porosity.

CONCLUSION

The welding of thick plates of high-strength aluminum alloys is somewhat less of a problem than it was several years ago. Advances in welding methods and

techniques and the development of improved filler-metal alloys will enable the design engineer to use strengths considerably above those used in the past. In the cases where postweld heat treatments can be used, joint efficiencies of 100% in 61S, 80 to 90% in 24S, and 50 to 60% in 75S can be obtained with useful ductility. At present, the design of "as-welded" joints may be based on joint efficiencies of 70 to 80% in 61S, 60 to 70% in 24S, and 50 to 60% in 75S.

Although several filler-metal alloys have been developed which have strength properties higher than those of 61S-T6, the design strengths for 61S-T6 weldments are limited by the strength of the heat-affected zone, i.e., 70 to 80% of the strength of the unaffected base metal. Therefore, when high-strength filler metals are used, weldments in 61S-T6 will invariably fail in the heat-affected zone.

In the case of 24S-T4 and 75S-T6 plates, no filler metals have been developed as yet that have the strength of the heat-affected zone and have sufficient ductility to be useful. Weldments in thick plates of these alloys normally fail in the weld metal, so that there is some room for improvement in the design of filler metals for 24S and 75S weldments. In any event, the limit of design strength will be the strength of the heat-affected zone, when postwelding heat treatment is not used.

The obvious solution to the problem of obtaining high as-welded joint efficiencies is to use alloy base plates which are not affected by welding heat. Aluminum-magnesium alloys are good examples. Although such alloys have found wide applications as structural material in Europe, their use in this country has been limited by lack of demand, because special techniques are required in their manufacture and because of their perhaps undeserved reputation for susceptibility to stress corrosion.

Another solution to the welding heat problem would be to use a process requiring no heat or at most temperatures lower than 300° F, i.e., cold welding. However, the process is now limited to relatively thin sections. It will be several years, if ever, before this process can be developed to the point where it could be used in thick plates of aluminum alloys.

The introduction of the inert-gas-shielded consumable-electrode process has been a tremendous step forward in the welding of aluminum. As with any new process, there are certain problems that must be worked out. One of the main difficulties in the use of this welding process is the porosity that is likely to be encountered in the weld metal. The porosity is believed to be due to hydrogen present as water vapor or hydrated aluminum oxide on the surface of the filler-metal wire and base plates and to hydrogen occluded within the metals themselves. Careful attention to the cleanliness of filler-metal wire and base plates helps considerably in the reduction of porosity as does the use of proper welding techniques. Perhaps refinements in aluminum manufacturing techniques will eventually eliminate the problem of weld-metal porosity.

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(Continued on page 208-s)

Control of Penetration and Melting Ratio with Welding Technique

Useful formulas have been developed for estimating the penetration characteristics of a weld given the machine welding settings

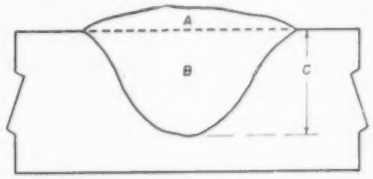
by Clarence E. Jackson and Arthur E. Shrubsall

Abstract

The penetration and melting ratio have been measured for a large number of submerged arc and coated electrode welds in commercial quality steel using various joint designs. The measurements correlate well with the welding settings of current, arc voltage and travel speed, and are presented in this paper as formulas and alignment charts. These are useful in estimating the penetration characteristics of a weld given the welding settings, and also should be useful in selecting welding settings for a desired performance. The relationships for melting ratio to welding technique have shown definite trends but additional factors must be investigated in order to make this fully quantitative.

INTRODUCTION

THE welding engineer is often confronted with a problem of setting up a welding technique for conditions outside the field of available experience. Generally, the initial welding conditions for making a particular joint are determined from tables based on previous accumulated data, or from a guess based on previous experience. Good engineers will be able to guess closer than those with less experience. It is the purpose of this paper to present a number of relationships which have been found to exist between the variables which establish a welding technique and the performance of that welding technique. Such factors as welding current and voltage, and speed of travel are generally considered the most important factors which are subject to the engineer's control. These will be considered, and empirical relationships will be presented which have been useful in establishing new techniques to produce a required weld.



A= Reinforcement
B= Base metal melted
C= Penetration

$$\text{Melting Ratio} = \frac{B}{A+B}$$

Fig. 1 Bead weld deposited on a flat plate

Such factors as welding current or voltage, polarity, rate of travel, and diameter and type of electrode, as well as type of coating or Unionmelt welding composition have received attention by various investigators. Usually a single factor is the subject of an investigation. Occasionally, several items are lumped into one parameter, such as power input, and related to penetration and melting ratio. A general solution, however, is essential in order to separate the effects of the various components.

Previous papers[1,2] have discussed the relationship of welding technique to energy distribution and ductility. In this paper, two additional factors, penetration and melting ratio, are considered.

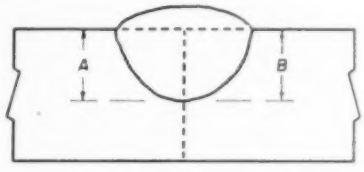
PENETRATION

The penetration of a bead weld deposited on a surface of a plate is generally recognized as the distance below the surface of the plate to which the molten metal progresses (Fig. 1). The AMERICAN WELDING SOCIETY Committee on Definitions does not present a general definition for penetration, but defines (*a*) joint penetration and (*b*) root penetration.[3] Joint penetration is described as the minimum depth a groove weld extends from its face into a joint, exclusive of reinforcement (Fig. 2). Root penetration is defined as the depth a groove weld extends into a root of a joint measured on the center line of the root cross section (Fig. 2). Throughout this paper, the term "penetration" will be understood to mean "joint penetration" in accordance with this standard definition.

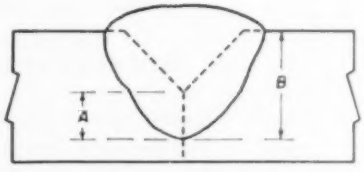
CRATER FORMATION

Little rhyme or reason could be found in the quantitative relationship between penetration and technique until it was realized that as far as the action of the welding arc was concerned, penetration could be measured only after the working level of the metal in the crater could be established. It is fortunate that for many welding techniques of complete joints, using the submerged melt or Unionmelt* welding process, the level of the crater

* The term "Unionmelt" is a registered trademark of Union Carbide and Carbon Corp.



BUTT JOINT



GROOVE PREPARATION

A= Root Penetration
B= Joint Penetration

Figure 2

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appears to be either at, or nearly at, the surface of the plate, the molten weld metal being driven back to form the crown of the weld bead or deposit in a machined groove.

In the formation of a crater, a number of factors act against surface tension to enlarge the crater. Some of these forces, listed by Lorenz[4] and Doan[5], are as follows:

(*a*) Reaction forces produced by the drops of metal being transmitted from the electrode to the weld puddle.

(*b*) The effect of the impulse of charged carriers in the welding zone.

(*c*) Electrodynamic force caused by the current emerging from a small conducting cross section to the larger crater section.

(*d*) Forces due to rapid expansion of the volume of gases released from the weld zone.

(*e*) Forces due to reaction of metal vaporized from the electrode.

In order to evaluate the importance of some of these forces, let us discuss the possibilities of item (*a*), the reaction forces of the drops of metal being transmitted from the electrode to the weld puddle. Since exact measurements of the velocity of drop transfer by use of ultra-slow motion pictures of a shielded-inert-gas metal arc have been reported by Gillette and Breymeier,[6] these will be reviewed first. In a weld using 600 amp direct current with reverse polarity, a final velocity of the molten particles was found to be approximately 900 ips. Over 700 particles were transferred per second, with a mass per drop of 25×10^{-6} lb, and a melting rate of 0.35 lb/min. These data, taken from measurements on individual frames or sequences of them, indicate the presence of large reaction forces. When it is noted that these data show that with a 600-amp welding current, 0.35 lb of electrode is fused per minute and that the final velocity is in the order of 50 mph, only then can the extent of the reaction forces be realized. A recognition of the other factors which are ordinarily considered, such as the volume expansion of the gases in the weld zone and vaporization of metal from the electrode, together with the more vague electrodynamic forces, indicates that forces tending to create a crater must be extensive.

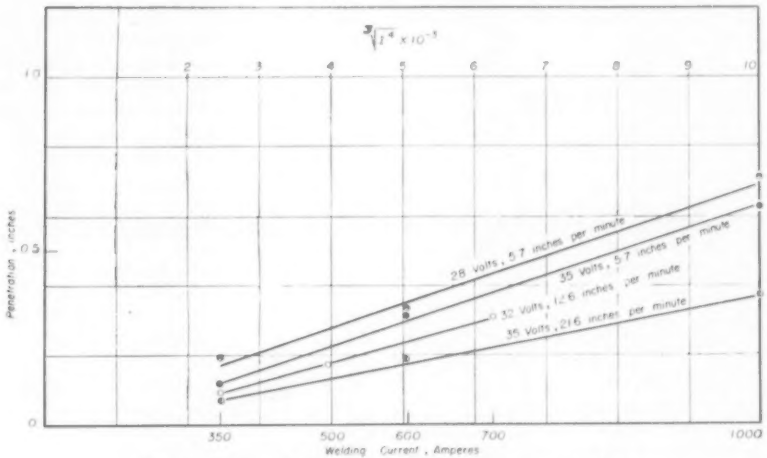

$\sqrt[3]{I^4} \times 10^{-3}$
Penetration , inches
Welding Current , Amperes
28 Volts , 5.7 inches per minute
35 Volts , 5.7 inches per minute
32 Volts , 12.6 inches per minute
36 Volts , 21.6 inches per minute

Fig. 3 Effect of changes in current on penetration

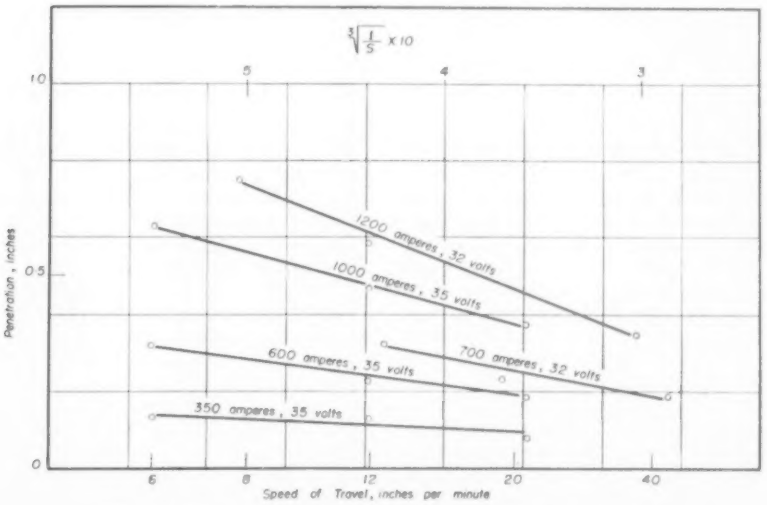

$\sqrt[3]{\frac{I}{S}} \times 10$
Penetration , inches
Speed of Travel , inches per minute
1200 amperes , 32 volts
1000 amperes , 35 volts
600 amperes , 35 volts
700 amperes , 32 volts
350 amperes , 35 volts

Fig. 4 Effect of changes in speed of travel on penetration

EFFECT OF WELDING TECHNIQUE ON PENETRATION

In setting up a welding technique with a given arc-welding process, the parameters which may be varied are current (I), travel (S) and voltage (E). Other factors, such as groove preparation, composition of electrode and the material being welded, will be specifically discussed. But first, let us attempt to establish a broad general basis for proceeding.

Current

A study of the effect of current on penetration, with constant voltage and speed of travel, demonstrates that the penetration increases as the current is increased. This relationship is not a linear one, and there is evidence presented by Gunnert[7,8] that penetration can be expressed numerically by the following formula:

$$P = K_1 \sqrt[3]{I^4}$$

where

P = penetration, in.
I = current, amp.
K_1 = constant depending upon characteristics of the welding process.

The data for a number of tests using the above relationship are shown in Fig. 3.

The melting rate of the electrode seems to be almost independent of the speed of travel. The welding composition fused per second also is not significantly influenced by changes in the travel speed. There is, however, a rather complicated relationship between penetration and travel. Recent tests have shown that the penetration for a constant current and voltage is expressed by the relationship,

$$P = K_2 \sqrt[3]{\frac{I}{S}}$$

where

S = travel, ipm.
K_2 = constant depending upon characteristics of the welding process.

The data for a number of tests by Gunnert,[7,8] using the above relationship, are shown in Fig. 4.

Voltage

The selection of a voltage suitable for any particular level of welding conditions should be such that a normal amount of welding composition is fused. A voltage that is too low will give erratic behavior (short circuits) and erratic penetration. As the voltage is increased, the amount of welding composition fused will increase.

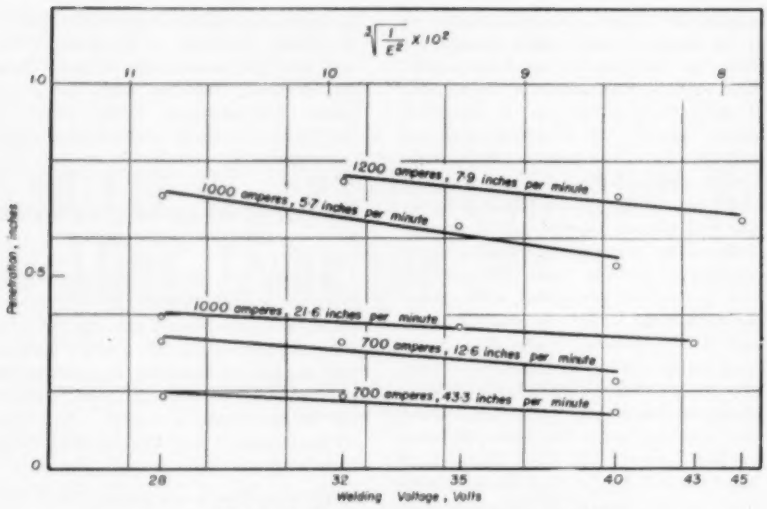


Fig. 5 Effect of changes in voltage on penetration

The weld will become wider, and penetration below the top surface of the plate will decrease. The energy required to fuse additional welding composition reduces the energy available for melting the plate. Furthermore, as the weld becomes wider, due presumably to the spreading of the arc spot, the arc force is less concentrated. Both effects result in less penetration. For surface beads, the relationship of penetration and changes in voltage in accordance to Gunnert appears to be given by the equation:

$$P = K_2 \sqrt{\frac{1}{E^2}}$$

where

E = welding voltage, v.
K_2 = constant depending upon characteristics of the welding process.

The data for a number of tests using the above relationship are shown in Fig. 5.

Combined Effect of Voltage, Current and Travel

If the relationships established for voltage (E), current (I), and travel (S) are assembled into one equation, the penetration (P) can be expressed by the following formula:

$$P = K \sqrt[3]{\frac{I^4}{SE^2}}$$

This equation is rather cumbersome and somewhat slow to calculate. In order to simplify this calculation the alignment chart shown in Fig. 6 is useful. The penetration can be readily calculated, provided the constant K has been determined. From the results which are available, this constant seems to be a characteristic and uniform for any given grade of Unionmelt welding composition, and has been found to range from 0.0010 to 0.0019. With standard commercial grades of Unionmelt welding composition, the range of K is generally from 0.0010 to 0.0013. The re-

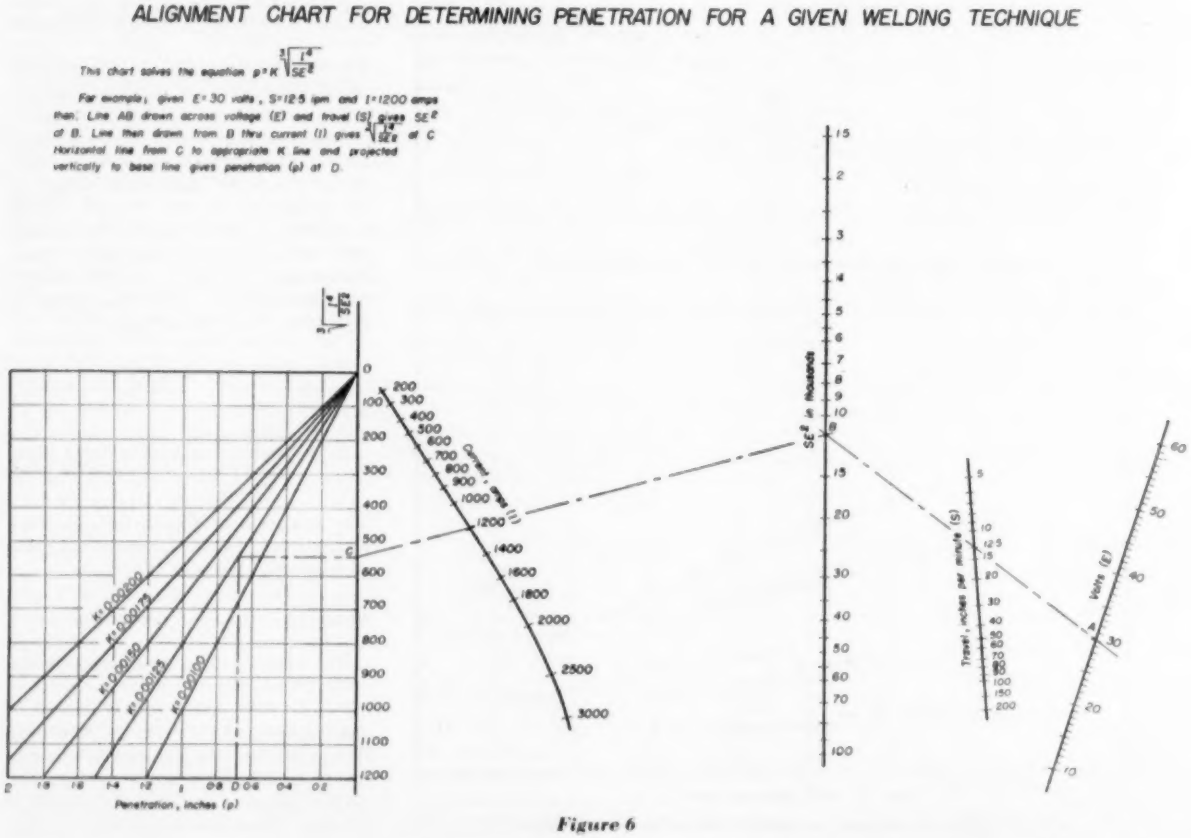

ALIGNMENT CHART FOR DETERMINING PENETRATION FOR A GIVEN WELDING TECHNIQUE
This chart solves the equation $p = K\sqrt[3]{\frac{I^4}{SE^2}}$
For example; given E = 30 volts, S = 12.5 ipm and I = 1200 amps then: Line AB drawn across voltage (E) and travel (S) gives SE^2 at B. Line then drawn from B thru current (I) gives $\sqrt[3]{\frac{I^4}{SE^2}}$ at C. Horizontal line from C to appropriate K line and projected vertically to base line gives penetration (p) at D.
$\sqrt[3]{\frac{I^4}{SE^2}}$
K = 0.00300
K = 0.00173
K = 0.00152
K = 0.00133
K = 0.00100
Penetration, inches (p)
Current, amps (I)
SE^2 in thousands
Travel, inches per minute (S)
Volts (E)
A
B
C
D

Figure 6

sults for a number of tests for Grade 20 Unionmelt welding composition for which complete welding techniques and penetrations were available, are shown in Fig. 7.

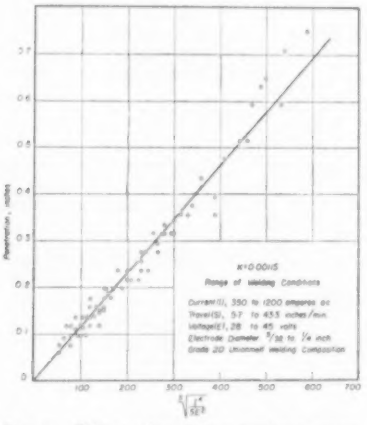

K=0.00115
Range of Welding Conditions
Current (I), 350 to 1200 amperes ac
Travel (S), 57 to 455 inches/min.
Voltage (E), 28 to 45 volts
Electrode Diameter 5/32 to 1/4 inch
Grade 20 Unionmelt Welding Composition
Penetration, inches

Fig. 7 Effect of welding technique on penetration

A line for $K = 0.00115$ has been drawn in. In another series of tests with a coated electrode of the E6015 lime-type class, results shown in Fig. 8 can be plotted. A line for $K = 0.00130$ has been drawn in. The K value, it must be understood, is a characteristic for a given electrode or welding composition, and at the present time has no recognized physical significance but merely is the relation between penetration and the expression:

$$\sqrt[3]{\frac{I^4}{SE^2}}$$

for a given series of welding tests using a uniform lot of material.

EFFECT OF OTHER VARIABLES ON PENETRATION

It is recognized that other factors besides welding current, travel and voltage may influence the penetration relationship. Some of these variables are worthy of comment.

Groove Preparation

As a general observation, the use of prepared bevels will not influence the penetration, provided the welding crater exists essentially at the top surface of the plate or measurements are taken of penetration below the welding surface of the crater. No convenient means are available for measuring the level of the molten metal in the welding crater during welding. However, an approximate answer can be obtained from the level of the solid crater produced by quickly breaking the welding current at the end of a weld. Further studies of weld metal dynamics would be helpful.

In order to observe the effect of the angle of the groove, three welds were made, with joints prepared as shown in Fig. 9.

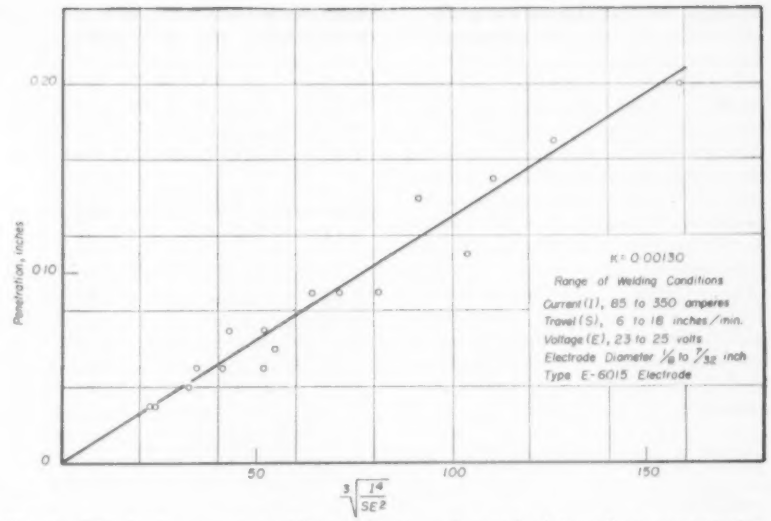


Fig. 8 Effect of current, welding voltage and speed of travel on penetration

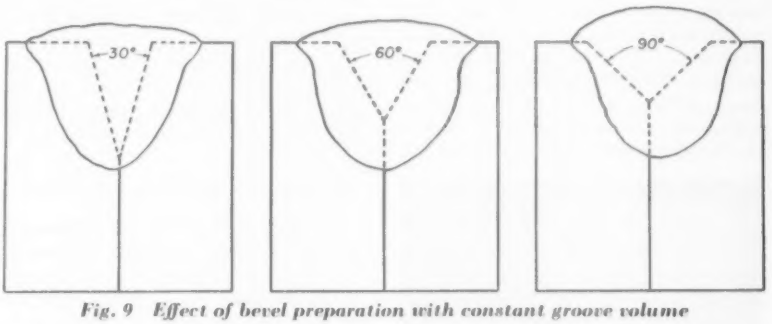


Fig. 9 Effect of bevel preparation with constant groove volume

The area of the cross section of the groove in each case was equal to 0.056 sq in. and increased in depth from 0.24 to 0.31 to 0.46 in. as the groove angle decreased from 90 to 60 to 30 deg. These joints were welded using 850 amp a c, 28 v and 16 ipm travel. The following results were obtained:

Bevel angle, deg	*Bevel depth, in.*	*Penetration, in.*
30	0.46	0.50
60	0.31	0.51
90	0.24	0.46

Such results indicate that bevel preparation is not a major factor in controlling penetration. However, with extreme changes, such as shown in Fig. 10, in which welds are deposited on the surface of a plate and in a bevel preparation, the penetration below the surface of the plate will vary. The level of the weld metal in the crater for the surface deposit was well above the top surface of the plate, while the level of the crater for the bevel preparation was essentially at the top surface of the plate.

In another series of three welds in 2-in. thick plate with a current of 2250 amp a c, 7½ ipm travel, and voltage increasing from 43 to 46 to 50 v, an anomalous behavior was noted in that the penetration

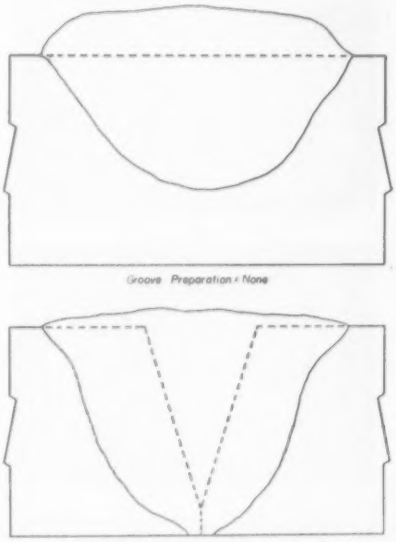
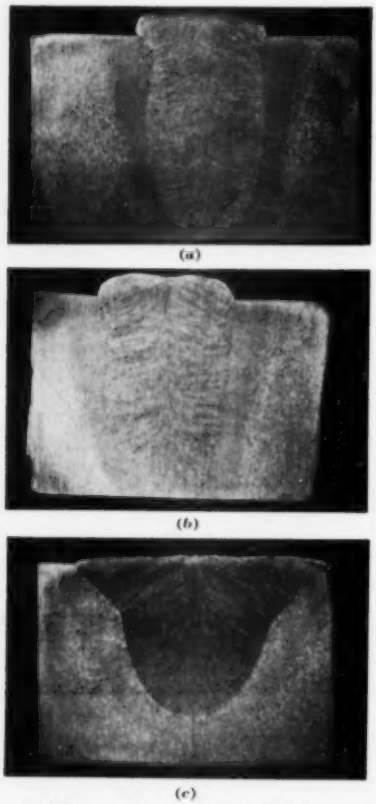


Fig. 10 Profile of weld deposits obtained with Grade 20 Unionmelt welding composition

decreased more than expected with a voltage increase (Fig. 11). After inspection of the cross section and the weld craters, the results were brought into line when penetration was measured from the bottom of the crater. In the weld made with 50 v, the crater was level with the top surface of the plates, giving a K value of 0.00139, while in the weld made with 46 v, the crater level was approximately $^3/_8$ in. below the top surface of the plate, and the weld made with 43 v showed a crater level at approximately $^1/_4$ in. below the top surface of the plate. Hence, the weld cross sections with excess penetration, which at first consideration appear anomalous, were entirely in accord with the general relationship set up for penetration.

Electrode and Base Metal Composition

It is generally recognized that changes in electrode and base metal compositions will influence the penetration. For example, the use of a copper electrode for making a deposit on steel will result in a reduction in penetration in the base metal. In welding steels with steel electrodes, the carbon content of both the electrode and base metal influences penetration. Using a given steel electrode, the penetration is lowest for very low-carbon steel plates and gradually increases with carbon up to approximately 0.10%. From 0.10 to 0.13% carbon, the penetration remains essentially constant and for increasing carbon contents, the penetration is further increased. This has been shown to be related to the solidus temperature[9] for iron-carbon alloys.



(a) 2250 amp, 43 v, $7^1/_2$ ipm. (b) 2250 amp, 46 v, $7^1/_2$ ipm. (c) 2250 amp, 50 v, $7^1/_2$ ipm.

Fig. 11 Cross sections of welds made in 2-in. thick plate using a high-current Unionmelt welding composition. × 0.7

Unionmelt Welding Composition or Electrode Coating

In the Unionmelt process the various grades of welding composition will show a penetration with a given welding technique related to the value of K in Fig. 6. It has not been possible to establish definitely the factors which control the value of this constant, although it appears that such characteristics as ionization potential, energy distribution and conductivity of the welding composition are important.

Penetration measurements on welds made with several commercial, coated electrodes reveal differences in K of the same order of magnitude as for submerged-arc welding compositions. There is one difference, however, as in many coated electrodes the flux may form a more or less extended solid envelope around the arc, which constricts the freedom of the arc spot, thus increasing penetration.

Modifications of Welding Process

In using coated electrodes manually, the operator often inclines the electrode so as to direct the force of the arc back on the deposited metal which cushions the base metal, thus reducing the base metal penetration. It must be remembered that such a technique generally aims at raising the level of the crater, and since it has been shown that penetration is measured from the level of the molten metal in the crater, this will result in less penetration.

Other special techniques, such as the introduction of an auxiliary electrode to be melted in the arc stream, are also aimed at the building up of the level of the crater, thus decreasing the penetration into the base metal. The use of multiple electrode with series-arc technique[10] is a typical special procedure aimed at a decreased base metal penetration.

APPLICATION OF CONCEPTS

In order to illustrate the application of some of the principles which have been presented in the foregoing discussion, actual examples will be used. The question is raised as to whether the following techniques will be approximately satisfactory.

Example a:
Thickness, 0.063 in., steel.
Type of joint, square-edge butt, copper backing.
Current, 260 amp.
Voltage, 22 v.
Travel, 80 ipm.
Unionmelt welding composition, Grade 90 (20 by 200 mesh).
Check: Assuming a K value of 0.0012, then (Fig. 7)

$$p = K\sqrt[3]{I^4/SE^2} = 0.0012\sqrt[3]{260^4/80 \times 22^2} = 0.059 \text{ in.}$$

Example b:
Thickness, 0.203 in., steel.
Type of joint, square-edge butt, copper backing.
Current, 620 amp.
Voltage, 26 v.
Travel, 36 ipm.
Unionmelt welding composition, Grade 90 (20 by 200 mesh).
Check: Assuming a K value of 0.0012, then (Fig. 7)

$$p = K\sqrt[3]{I^4/SE^2} = 0.0012\sqrt[3]{620^4/36 \times 26^2} = 0.218 \text{ in.}$$

Example c:
Thickness, 0.43 in., steel.
Type of joint, 25 deg with $^1/_8$-in. root face.
Current, 1150 amp.
Voltage, 30 v.
Travel, 35 ipm.
Unionmelt welding composition, Grade 90 (20 by 200 mesh).
Check: Assuming a K value of 0.0012, then (Fig. 7)

$$p = K\sqrt[3]{I^4/SE^2} = 0.0012\sqrt[3]{1150^4/35 \times 30^2} = 0.45 \text{ in.}$$

Example d:
Thickness, 0.50 in., steel.
Type of joint, 60 deg with $^2/_{16}$-in. root face.
Current, 940 amp.
Voltage, 28 v.
Travel, 16 ipm.
Unionmelt welding composition, Grade 90 (20 by 200 mesh).
Check: Assuming a K value of 0.0012, then (Fig. 7)

$$p = K\sqrt[3]{I^4/SE^2} = 0.0012\sqrt[3]{940^4/16 \times 28^2} = 0.48 \text{ in.}$$

MELTING RATIO

The welding engineer is always interested in penetration, for it determines the stress-carrying value of a weld. When he is concerned with hard-surfacing or with welding dissimilar metals, he may be more interested in melting ratio than in penetration. The melting ratio, sometimes referred to as dilution, expresses the extent to which the composition of the base metal is changed by admixture with weld metal from the electrode. While not defined by the American Welding Society Committee on Definitions, melting ratio is generally considered as the ratio of the cross-sectional area of the weld metal below the original surface of base metal to the total area of the weld, measured on a cross section of the joint or deposit, Fig. 1. The higher the melting ratio, the more nearly the deposit will conform in composition to the base metal.

In a previous publication,[1] the melting rate of an electrode was shown to be essentially proportional to the current, Figs. 12 and 13. Thus,

$$M = BI$$

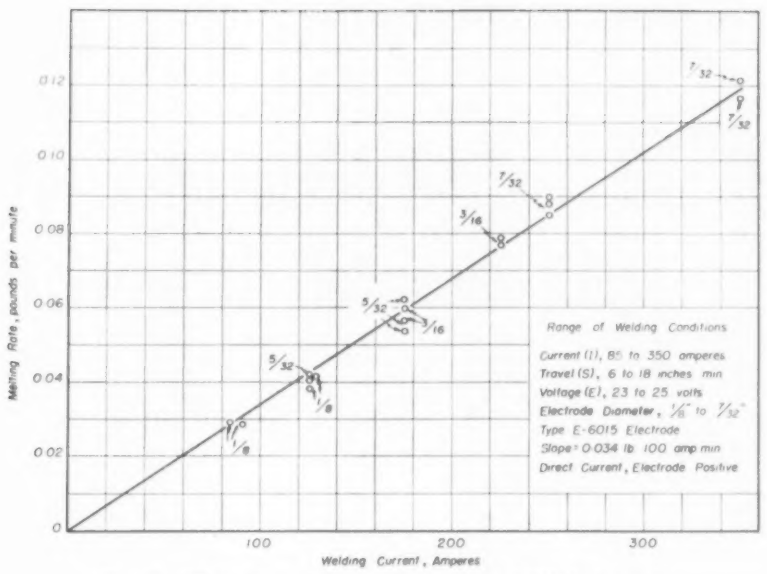

Melting Rate, pounds per minute
Welding Current, Amperes
Range of Welding Conditions
Current (I), 85 to 350 amperes
Travel (S), 6 to 18 inches min
Voltage (E), 23 to 25 volts
Electrode Diameter, 1/8" to 7/32"
Type E-6015 Electrode
Slope = 0.034 lb 100 amp min
Direct Current, Electrode Positive

Fig. 12 Effect of current on melting rate of E6015 electrode

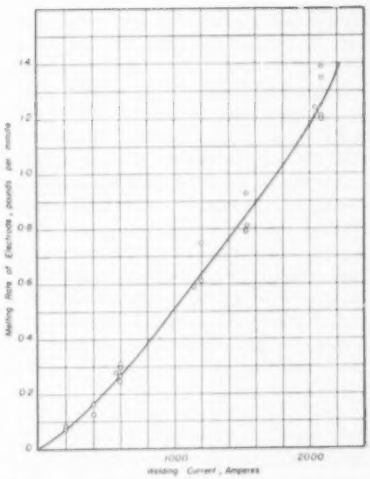


Fig. 13 Effect of welding current on melting rate of electrode using Grade 20 Unionmelt welding composition

where

M = melting rate, lb./min.
B = a constant.
I = current, amp.

From this, the reinforcement (R) of a bead weld deposited with a travel speed (S) will be given by

$$R = BI/S \qquad (1)$$

Also in a previous publication,[1] Fig. 14, the cross-sectional area of a bead weld was shown to be given by the following equation:

$$\log A = 0.435 \log \left(\frac{I^{1.716}}{S}\right) - 1.57$$

This can be rewritten as

$$A = C\,(I^{0.716}/S^{0.435}) \qquad (2)$$

where

A = cross-sectional area of weld nugget, sq in.
C = a constant.
I = current, amp.
S = travel, ipm.

From eqs 1 and 2, the melting ratio can, according to definition, be stated as

$$M_r = 100 - \frac{BI/S}{/C(I^{0.716}/S^{0.435})}$$

$$M_r = 100 - D\,(I^{0.284}/S^{0.565}) \qquad (3)$$

where

M_r = melting ratio in percent base metal in weld nugget.
I = welding current, amp.
S = travel, ipm.
D = a constant depending upon the area constant, C, and the melting rate constant, B.

For inspection, the relationship of M_r to $(I^{0.284}/S^{0.565})$ may be plotted, and from such data the value of D may be approximated. In establishing this relationship, voltage does not appear to be a controlling factor.

Data were available for a number of welds made with various grades of Unionmelt welding compositions. These data have been calculated and, as shown in Fig.

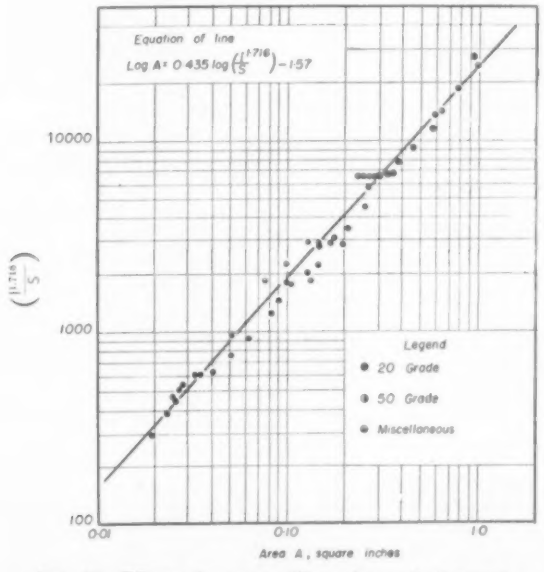


Fig. 14 Effect of current (I) and speed of travel (S) on cross-sectional area (A) of bead weld

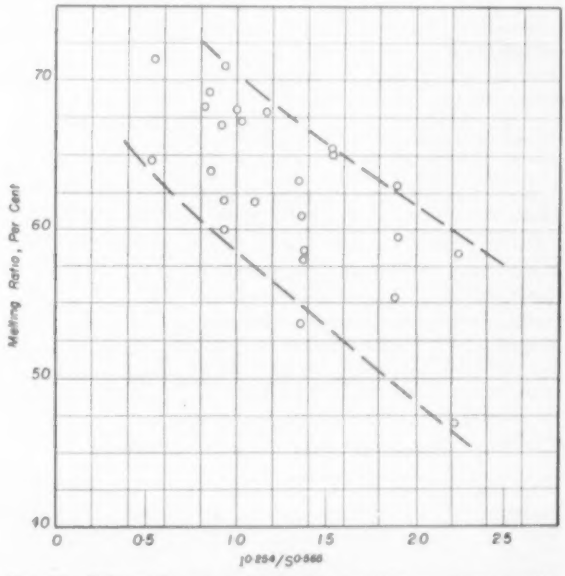


Fig. 15 Effect of current (I) and travel (S) on melting ratio with Grade 20 Unionmelt welding composition

15, the melting ratio for Grade 20 Unionmelt generally decreases as the value ($I^{0.254}/S^{0.565}$) increases. The relationship is not strictly linear. The scatter of approximately plus or minus 5% is apparently due to several factors. It is known that, in the formation of the welding crater, the arc force increases with current. Apparently, at high currents the arc blasts through the cushioning molten metal and impinges in a more direct manner on the base metal. It also appears quite likely that the molten weld metal is heated to a higher temperature during transfer with higher currents; this condition would tend to increase the base metal fused by a given welding technique.

As shown in Fig. 16, the available data for tests using Unionmelt Grades 50, 80, 85 and 90 show a trend which is sufficiently well defined to indicate the effect of welding current and speed of travel on the melting ratio. Grade 50 gives the lowest and Grade 80 the highest melting ratio for a given welding technique. A general inspection of these data will give a qualitative evaluation of the effect of current and travel on the percent of the base metal which is melted. For a given rate of travel, an increase in the welding current will decrease the melting ratio. With a given welding current, an increase in rate of travel will increase the melting ratio.

Further data regarding such factors as the forces acting in crater formation and measurements of weld metal temperature are needed to establish the relationship quantitatively. In two series of data with coated electrodes and lower currents, no relationship between the melting ratio and welding technique could be obtained. These data were subject to the effect of spatter and other variables.

CHECK TEST FOR MELTING RATIO

In order to check the ideas regarding melting ratios, a weld was made using an electrode and plate with the following composition:

	C, %	*Mn*, %	*Si*, %	*Mo*, %
Plate	0.19	0.58	0.22	0.009
Electrode	0.14	2.05	0.05	0.51

A surface deposit was made with Grade 20 Unionmelt welding composition using 900 amp a c, with 34 v, at a speed of travel of 10 ipm. A sample for chemical analyses was drilled longitudinally in the weld metal from the top, middle and bottom of the weld. The following results were obtained:

Location	*C*, %	*Mn*, %	*Si*, %	*Mo*, %
Top	0.12	0.58	0.55	0.18
Middle	0.12	0.61	0.56	0.18
Bottom	0.11	0.65	0.55	0.18
Av.	0.12	0.61	0.55	0.18

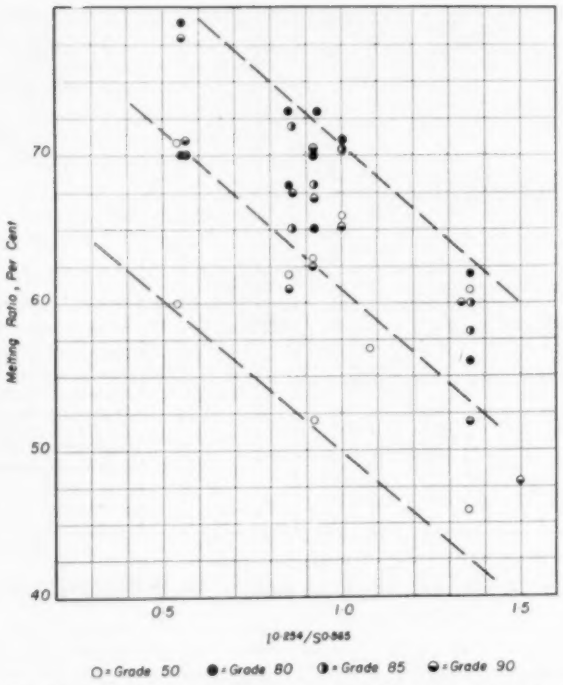


Fig. 16 Effect of current (I) and travel (S) on melting ratio with various grade of Unionmelt welding composition

From the chemical analyses for the molybdenum content, it is possible to calculate the melting ratio as 65.5%.

As a further check, actual areas were measured with a planimeter from a cross section of the weld, and the following areas were observed: Total weld area, 0.49 sq in; base metal melted, 0.32 sq in.

From this, the melting ratio is 0.32/0.49 × 100, or 64.8%, which corresponds closely with the value obtained from chemical analyses. This melting ratio, plotted on Fig. 15, follows the trend which has been presented.

SUMMARY

Penetration

The penetration of a weld below the level of the weld metal in the crater increases with welding current and decreases with an increase in either speed of travel or welding voltage.

Melting Ratio

The ratio of the base metal melted to the total weld metal decreases with welding current and increases with speed of travel.

Closure

In presenting the information in this paper, it is realized that many of the relationships are trends, although the Unionmelt welding process has been particularly useful in these studies since spatter losses accompanying open-arc processes are prevented by the blanket of welding composition. Some of the qualitative aspects of the discussion cannot be made more quantitative until further information is available regarding the mechanics of crater formation. In the open-arc processes, factors controlling spatter losses and deposit efficiency are insufficiently evaluated. However, over the past years, the information regarding the physics of the welding zone is gradually taking form, and this will lead to better control and better selection of welding techniques for a particular application and to new techniques for new applications.

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The Semiautomatic Inert-Gas Metal-Arc Welding of Aluminum Alloys

Tensile properties of welded joints is affected more seriously in the precipitation-hardened aluminum alloys than in the cold-worked and stabilized alloys

by Charles T. Gayley, Joseph R. Girini and Walter H. Wooding

Abstract

This paper presents data on the tensile properties of a variety of welded joints in several aluminum alloys. The welds were deposited using the inert-gas-shielded metal-arc welding process. One precipitation-hardened alloy and three cold-worked and stabilized alloys were used in the investigation. A comparison is made of the strength and joint efficiency of welds in the precipitation-hardened alloy and in the individual stabilized alloys. It is shown that the heat of welding has a far greater deleterious effect on the precipitation-hardened alloy than on the cold-worked and stabilized alloys with respect to proportional limit, yield strength and ultimate strength of the welded joint.

INTRODUCTION

RECENT notable advances in the art of welding aluminum and its alloys have reacted to greatly increase the industrial uses of these materials, particularly in the structural field. In turn, the increased use has led to a more searching analysis of the effects of welding on the various types of aluminum alloys. As a contribution to this renewed search, a study of the differences in the performance of welded joints in several aluminum alloys, representing the precipitation-hardened and the stabilized, was undertaken.

MATERIALS

The nominal chemical composition and tensile properties of the alloys selected to represent the two general types, the precipitation-hardened and the stabilized, are given in Table 1.

The 61S-T6 alloy represents the precipitation-hardened materials. Magnesium alloys 52S, 54S and 56S represent the alloys given a combination cold-work and stabilization treatment to impart a specific temper of H-34. It is to be noted that the principal difference in the magnesium alloys is the magnesium content. The higher the magnesium content, the higher the yield and tensile strength of the plate material.

The nominal tensile properties of the filler metals used in the investigation, as determined using 0.505-in. all-weld-metal specimens are as follows:

Alloy designation	*Yield strength, psi*	*Tensile strength, psi*	*Elongation, % in 2 in.*
43S	12,400	25,100	14
54S	16,000	30,600	22
56S	21,000	40,500	27

THE WELDING PROCESS

The welded joints used for comparing the welding characteristics of these alloys were deposited using semiautomatic inert-gas-shielded metal-arc welding equipment. Welds were deposited using $^1/_{16}$-in. diam. electrode wire, a helium shield of 150 cfh flow through a $^1/_2$-in. ID gas nozzle, an arc current of 160 to 200 amp and an arc voltage of 27 to 30. All multipass welds were deposited using a stringer bead technique. An interpass temperature of 100° F maximum was maintained in depositing all welds.

QUALIFYING OPERATORS

To qualify the operators used to deposit the test assemblies, a small V-groove weld was used. The test assembly is indicated in Fig. 1.

The pieces were firmly tacked and then clamped in a suitable jig so that warpage and angular distortion were

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Presented at the Thirty-Third National Fall Meeting, AWS, week of Oct. 20, 1952, Philadelphia, Pa. Closing date for discussion, May 15, 1953. The opinions and assertions contained herein are the private ones of the authors and are not to be construed as official, or reflecting the views of the Department of the Navy or the Naval service at large.

Table 1—Nominal Physical Properties and Chemical Composition of Plate Material

MATERIAL	CHEMICAL COMPOSITION							TENSILE PROPERTIES			
	COPPER %	IRON %	MANGANESE %	SILICON %	MAGNESIUM %	CHROMIUM %	ALUMINUM %	PLATE THICKNESS INCHES	YIELD STRENGTH P.S.I.	TENSILE STRENGTH P.S.I	ELONGATION IN 2 IN. %
61S-T6	.25	.40	-	.60	1.00	.25	REMAINDER	1/4	42000	45000	20
								3/8	42000	46000	20
								1/2	39000	43000	25
52S-H34	-	.15	-	-	2.50	.25	REMAINDER	1/4	30000	38000	15
								3/8	30000	37000	20
54S-H34	-	.15	-	.10	3.50	.25	REMAINDER	1/4	35000	43000	15
								3/8	-	42000	20
								1/2	-	42000	20
56S-H34	-	.15	.10	.10	5.25	.10	REMAINDER	1/4	37000	53000	15
								3/8	-	53000	20
								1/2	-	52000	20

NOTE :- TENSILE DATA OBTAINED WITH STRAP TYPE SPECIMENS (10-T)

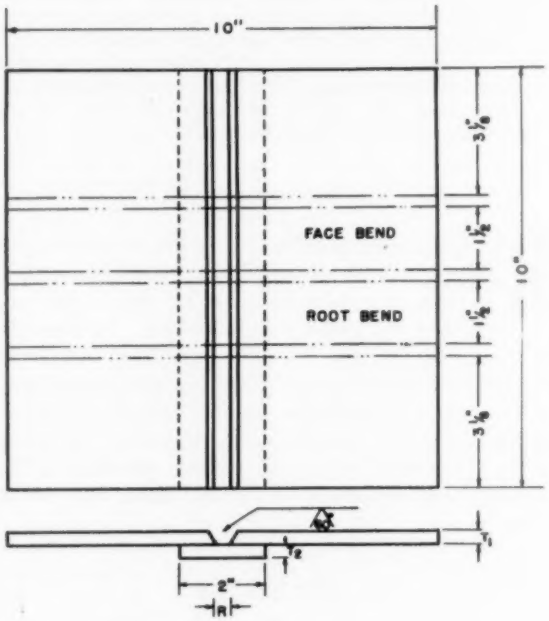
held to a 5 deg maximum. The operator was required to prepare one assembly in the vertical and one in the overhead position. Welding was accomplished without preheat and the interpass temperature was not permitted to exceed 100° F.

The welder's qualification test welds were deposited in 61S-T6 plates using A143S filler wire. The plates were annealed to a Brinell hardness of 35 (500-kg load) so as to more nearly match the hardness of the filler metal.

After completion, the welds were examined by X-ray methods without removal of the backing strap or weld reinforcement. The X-ray negatives were compared with a series of negatives showing a gradation in the amount of weld porosity. These negatives had been graded and given arbitrary ratings of A, B and C. The comparison negatives are reproduced as Fig. 2.

After X-ray examination face and root-bend specimens were removed and tested in a guided-bend test jig of the usual type to a bend radius of 3T, and 180-deg angle. Those specimens which on being bent showed cracks or openings exceeding $^1/_8$ in. in any direction were not considered satisfactory.

Specimens removed from welds of X-ray quality A and B all passed the guided-bend test. Specimens of X-ray quality C were border line with respect to the bend test. The relation between bend test results and X-ray quality is shown by Fig. 3.



WIRE SIZE	T1	T2	R
1/16"	1/4"	1/4"	1/4"

Fig. 1 Guided bend test specimens

TESTS

(a) Several types of welded assemblies were prepared in the precipitation-hardened alloy and in the

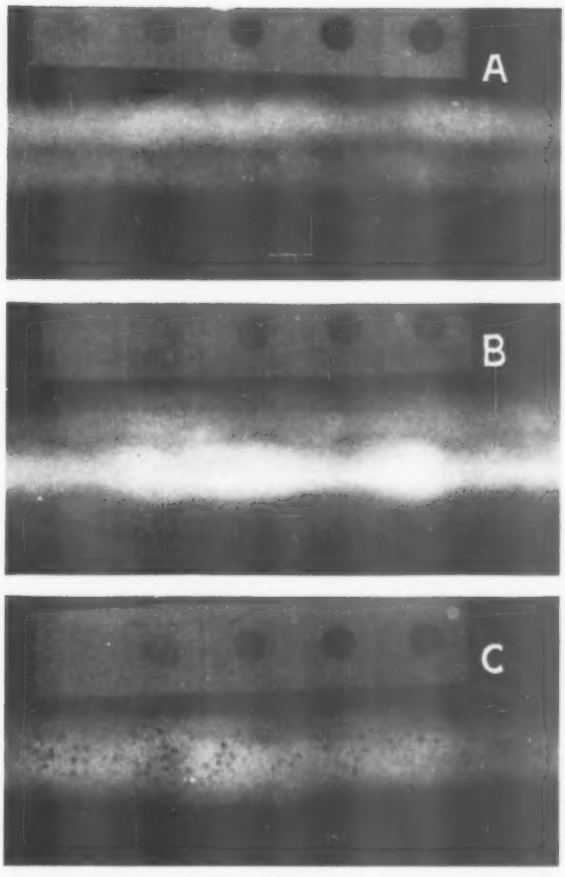


Fig. 2 X-ray standards, A, B, and C

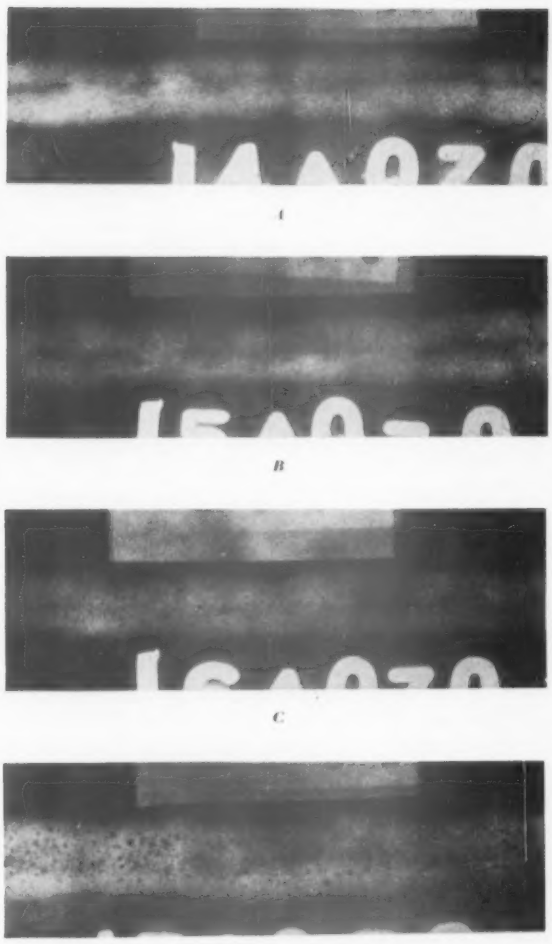
three stabilized alloys for the purpose of making a comparison of the performance of welded joints in the several alloys. The series of weldments included single-vee and double-vee groove welds, single-vee single-strapped groove welds and single-vee double-strapped groove welds.

The single-vee double-strapped butt joints were to determine the possibility of increasing the strength and efficiency of butt joints by adding fillet-welded straps on the face side of the weld. The effect of the width of strap and the fillet size were considered in this connection.

The size of assemblies and the size and preparation of the transverse tensile specimens used to obtain tensile data are indicated by Fig. 4. The joint preparation for several thicknesses of material together with the pass sequence is indicated by Fig. 5.

All butt welds were deposited using a multipass technique. Each pass was deposited by using a high arc travel speed, 20–40 ipm. An interpass temperature of about 100° F was maintained. By this technique the extent of the heat-affected zone was relatively narrow.

A143S filler wire was used to deposit the welds in 61S-T6 and 52S-H34. However, the A143S wire was not used for welds in the higher magnesium content



A

B

C

D

Fig. 3 X-ray quality required for satisfactory bend test (3T radius of bend)

A—Face and root bends satisfactory. *B*—Face and root bends satisfactory. *C*—Face bend satisfactory; root bend unsatisfactory. *D*—Face and root bends unsatisfactory.

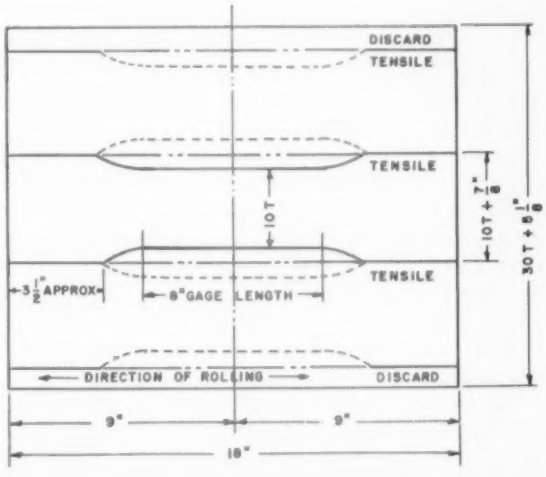


Fig. 4 Test plate cutting plan and detail of tensile specimens for tensile test assemblies

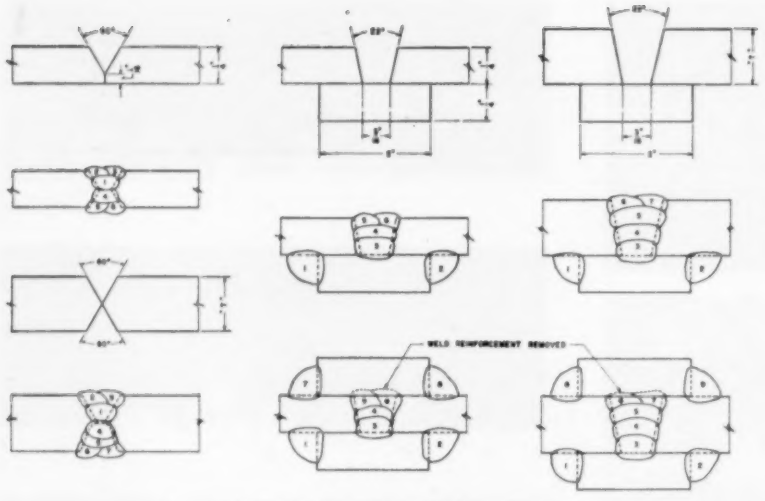


Fig. 5 Joint design and typical pass sequence

alloys. Previously it had been determined that when A143S filler wire is deposited on 54S and 56S alloys, the resulting diluted weld metal was subject to weld cracking even under moderate restraint. This dilution produced an alloy of about 2 to 3% magnesium and about 3% silicon. This particular alloy combination appears to be crack sensitive. Alloys 54S and 56S were therefore welded using filler metal having the same composition as the respective plate materials.

After welding, the test assemblies were first examined by X-ray methods and then three tensile specimens were removed from each assembly as indicated in Fig. 4. It is to be noted that the gage sections of the tensile specimens are 8 in. long and 10-T wide where T is the thickness of the plate material.

A specimen having a width over the gage length ten times the thickness of the plate was selected in order to introduce a greater degree of lateral restraint than is present when a narrow specimen is used. Further, the wide specimen should be less affected by any widely scattered weld flaws.

The yield strength and proportional limit of representative specimens of the three types of butt joints and for the four compositions of parent plate were determined as follows:

Strain was measured by two 8-in. phosphor bronze clip gages, each fitted with two type A3, "SR4" strain gages. A photograph of a butt joint specimen with the gages in position is presented as Fig. 6. The clip gages were used in conjunction with a Strain Gage Amplifier and a Direct Writing Recorder. A continuous strain record with corresponding load readings at 1000-lb increments in the elastic range and at 500-lb increments in the plastic range was recorded.

The data obtained in this manner were used to plot a stress-strain curve for each specimen. The yield strength was determined by drawing a straight line parallel to the elastic portion of the stress-strain curve at a distance corresponding to the offset of 0.2% strain. The stress corresponding to the point where this straight line intersects the stress-strain curve was taken as the yield strength.

(b) In order to obtain further information concerning the changes caused by the heat of welding, a hardness survey was made across a representative transverse section in each material. As a matter of convenience, the surveys were made across the welds at a point where the distance from fusion line to fusion line was $^1/_4$ in. and the heat-affected zones were about $^1/_8$ to $^1/_4$ in. wide. A Rockwell superficial hardness tester was used with a $^1/_{16}$-in. diam penetrator and a 15-kg load (15*T* scale).

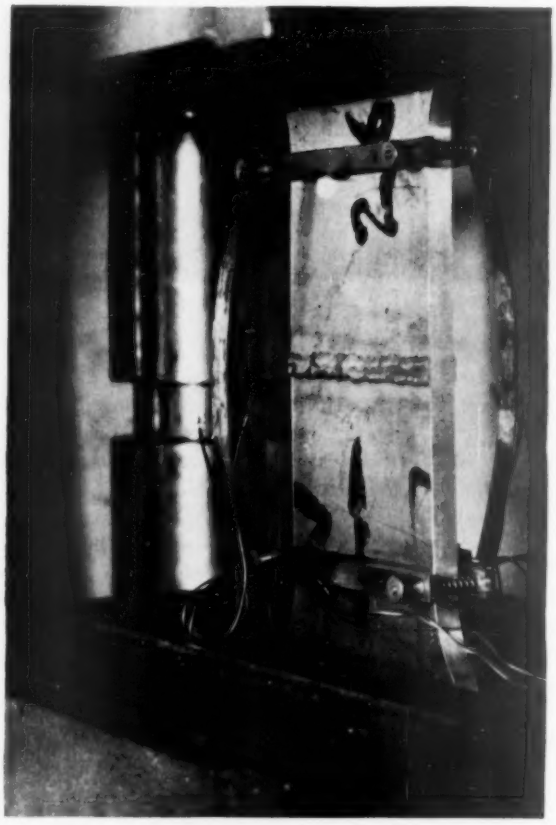


Fig. 6 Clip gage extensometer

RESULTS OF TEST

The results of test of the transverse strap-type specimens taken from the single- and double-vee groove weld assemblies are given in Table 2. Using the ultimate strength data from this table and the strength of the parent plate material given in Table 1, the per-

Table 2—Transverse Physical Properties of Aluminum Alloy Butt Welds Helium Shielded

JOINT DESIGN	WELDING POSITION		ALUMINUM ALLOY											
			52S-H34 (1)			54S-H34 (2)			56S-H34 (3)			61S-T6 (1)		
	GROOVE WELD	BACK WELD	ULTIMATE STRENGTH P.S.I. (4)	ELONGATION PERCENT (5)	LOCATION OF FRACTURE	ULTIMATE STRENGTH P.S.I. (4)	ELONGATION PERCENT (5)	LOCATION OF FRACTURE	ULTIMATE STRENGTH P.S.I. (4)	ELONGATION PERCENT (5)	LOCATION OF FRACTURE	ULTIMATE STRENGTH P.S.I. (4)	ELONGATION PERCENT (5)	LOCATION OF FRACTURE
60°, TYPICAL PASS SEQUENCE, BACK CHIPPED 1/8" DEEP, 1/2" RADIUS "U" GROOVE	O	F	-	-	-	40600	12.5	BASE METAL	46800	13.0	BASE METAL	31300	4.8	BASE METAL
	V	V	34700	8.2	BASE METAL	38300	9.0	BASE METAL	46200	9.7	BASE METAL	31600	3.0	BASE METAL
	H	H	-	-	-	42200	12.3	BASE METAL	49400	14.0	BASE METAL	31200	5.0	BASE METAL
80°, 60°, TYPICAL PASS SEQUENCE, BACK CHIPPED 1/8" DEEP, 1/2" RADIUS "U" GROOVE	O	F	34300	10.2	BASE METAL	38400	16.0	BASE METAL	48000	13.0	BASE METAL & WELD METAL	34900	2.5	BASE METAL
	V	V	33300	1.0	WELD METAL	38600	13.0	BASE METAL	46400	12.8	BASE METAL	32800	0.7	BASE METAL
	H	H	34000	6.8	BASE METAL	39500	13.7	BASE METAL	47700	11.8	BASE METAL	32400	4.6	BASE METAL & WELD METAL
60°, 60°, TYPICAL PASS SEQUENCE, BACK CHIPPED 3/16" DEEP, 3/8" RADIUS "U" GROOVE	O	F	-	-	-	38700	10.8	BASE METAL	43900	11.8	BASE METAL	31400	2.7	WELD METAL
	V	V	-	-	-	37500	16.3	BASE METAL	45700	11.7	BASE METAL	30600	3.2	BASE METAL & WELD METAL
	H	H	-	-	-	37900	17.9	BASE METAL	44800	13.3	BASE METAL	30500	3.0	WELD METAL

NOTES - 1. ALUMINUM ALLOY 43S FILLER WIRE
2. " " 54S " "
3. " " 56S " "
4. AVERAGE OF THREE SPECIMENS
5. " " " " ELONGATION TAKEN IN 2" ACROSS FRACTURE

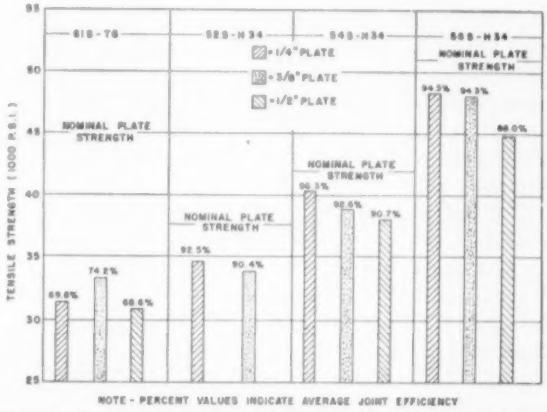
cent joint efficiencies were calculated. The results are presented graphically as Fig. 7.

It is to be noted that the joint efficiencies of 61S-T6 alloy, the precipitation-hardened alloy, are in the range of 70 to 75% and are considerably below the 90% or better for the stabilized alloys 52S, 54S and 56S.

The results for the single-vee single-strap butt joints are given in Table 3. Graphic presentation of the same data is given by Fig. 8. The 54S alloy has maintained about the same level of joint efficiency, the 56S has dropped and the 61S-T6 made a slight average gain.

The data with respect to the effect of varying the strap width of the single-strap butt joints is not quite consistent. However, there appears to be a slight tendency to higher joint efficiency of the 61S-T6 material with increase in width of strap. In view of the little difference in the effect of strap width, the 54S and 56S alloys were tested using only the 2-in. straps.

Figure 9 is presented to show a comparison between single and multipass welding procedures as measured by joint efficiency. Since the fractures were in the base metal at the toe of the fillets, the joint efficiencies



NOTE - PERCENT VALUES INDICATE AVERAGE JOINT EFFICIENCY

Fig. 7 Strength and efficiency of welded aluminum double-bevel double-vee butt joints based on transverse tensile properties

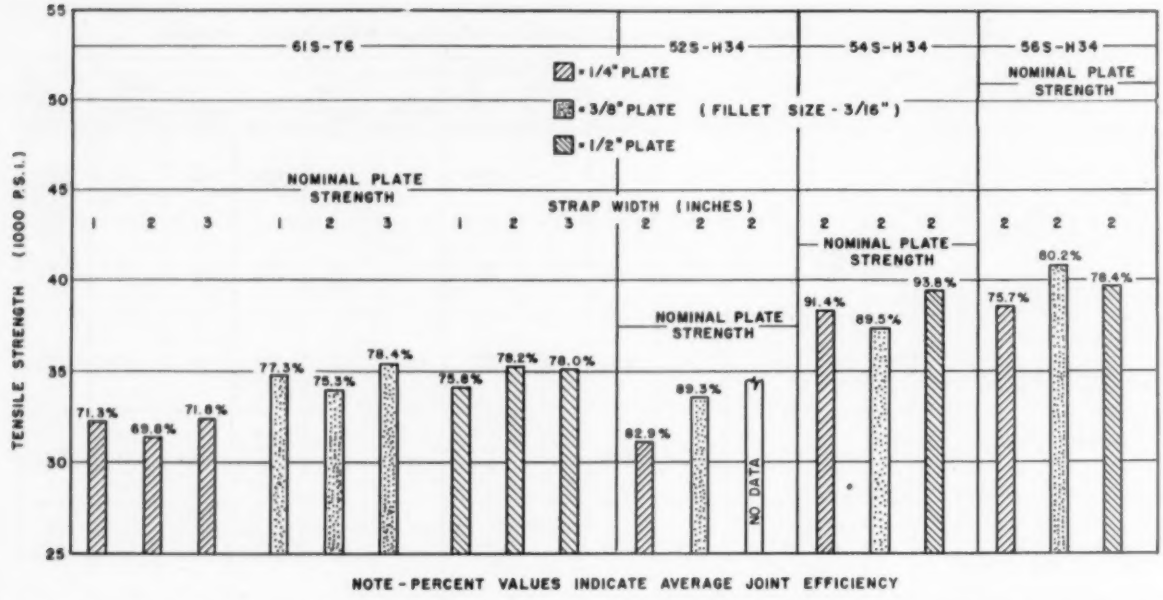


Fig. 8 Strength and efficiency of welded aluminum single-strapped double-bevel single-vee butt joints based on transverse tensile properties

should be an indication of the effect of the heat of welding on the base plate. The $^3/_8$-in. fillets on $^3/_8$-in. thick straps were deposited in three passes. All others were deposited in one pass. In all cases the joints with multipass fillet welds exhibit a higher joint efficiency than the joints with the $^5/_{16}$-in. fillets deposited in a single pass.

The results of test of the double-strapped butt joints are given in Table 4 and are presented graphically as Fig. 10.

The use of straps of unequal widths, so that no two fillet welds were located adjacent to each other would appear to be a promising way of increasing the joint efficiency. However, the data indicates the exact opposite. In general, joints with the two straps of equal width placed opposite each other exhibited the highest joint efficiency. This is true regardless of plate thickness. The better performance of the joints with straps of equal width probably lies in the fact that these joints have a more uniform stress distribution when under a tensile load.

The higher joint efficiency of the double-strapped joints with straps of equal width is further indicated by Table 5 and Fig. 11. The figure also indicates that an increase in joint efficiency may be obtained by depositing the $^5/_{16}$-in. fillets with a multipass technique, as was also shown for the single-strap joints by Fig. 9. The highest joint efficiencies in alloys

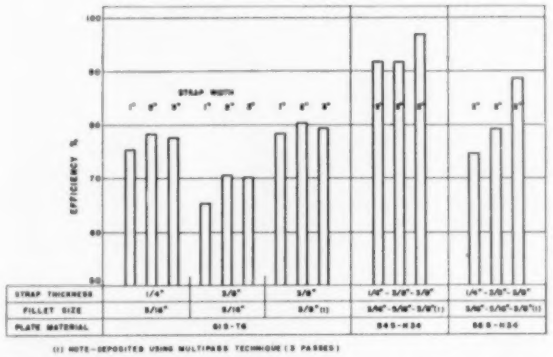


Fig. 9 Efficiency of welded aluminum single-strapped double-bevel single-vee butt joints $^1/_2$-in. plate material based on transverse tensile properties

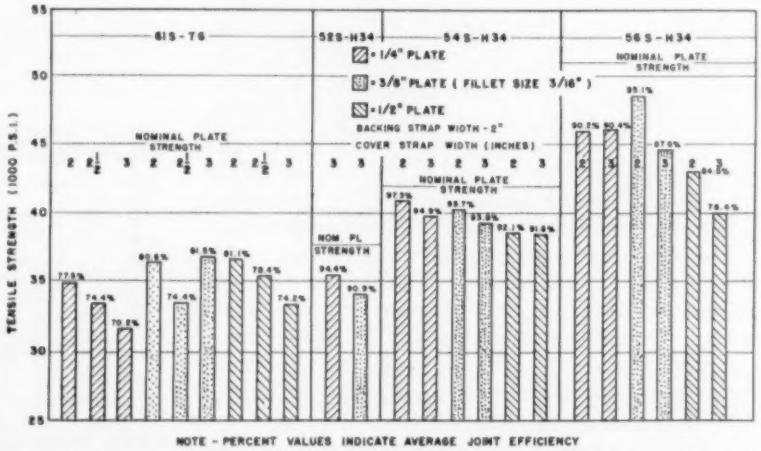
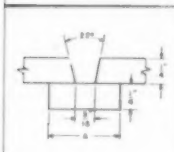
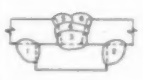
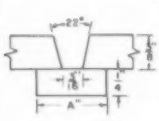
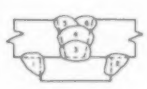
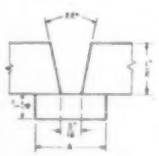
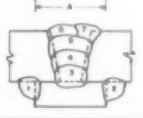


Fig. 10 Strength and efficiency of welded aluminum double-strapped double-bevel single-vee butt joints based on transverse tensile properties

Table 3—Transverse Physical Properties of Aluminum Alloy Single-Strap Butt Welds Helium Shielded

JOINT DESIGN	WELDING POSITION	STRAP WIDTH "A"-IN.	FILLET SIZE IN.	ALUMINUM ALLOY 52S-H34 (1) ULTIMATE STRENGTH P.S.I. (4)	52S-H34 (1) ELONGATION PERCENT (5)	52S-H34 (1) LOCATION OF FRACTURE	54S-H34 (2) ULTIMATE STRENGTH P.S.I. (4)	54S-H34 (2) ELONGATION PERCENT (5)	54S-H34 (2) LOCATION OF FRACTURE	56S-H34 (3) ULTIMATE STRENGTH P.S.I. (4)	56S-H34 (3) ELONGATION PERCENT (5)	56S-H34 (3) LOCATION OF FRACTURE	61S-T6 (1) ULTIMATE STRENGTH P.S.I. (4)	61S-T6 (1) ELONGATION PERCENT (5)	61S-T6 (1) LOCATION OF FRACTURE
	0	1	3/16	-	-	-	-	-	-	-	-	-	52100	6.2	BASE METAL
	0	2	3/16	-	-	-	38400	9.3	BASE METAL	38800	7.5	BASE METAL	51400	5.3	BASE METAL
	0	3	3/16	-	-	-	-	-	-	-	-	-	52300	6.2	BASE METAL
	0	1	3/16	-	-	-	-	-	-	-	-	-	34800	2.7	BASE METAL
	0	2	3/16	33500	9.8	WELD METAL	37400	12.1	BASE METAL	40900	8.3	BASE METAL	33900	2.3	WELD METAL
	0	3	3/16	-	-	-	-	-	-	-	-	-	35300	2.6	WELD METAL
	0	1	3/16	-	-	-	-	-	-	-	-	-	34100	3.2	BASE METAL
	0	2	3/16	-	-	-	39400	11.2	BASE METAL	39800	9.0	WELD METAL	38200	5.2	WELD METAL
	0	3	3/16	-	-	-	-	-	-	-	-	-	35100	4.2	WELD METAL

NOTES - 1. ALUMINUM ALLOY 43S FILLER WIRE
2. " " 54S " "
3. " " 56S " "
4. AVERAGE OF THREE SPECIMENS
5. " " " " ELONGATION TAKEN IN 2" ACROSS FRACTURE

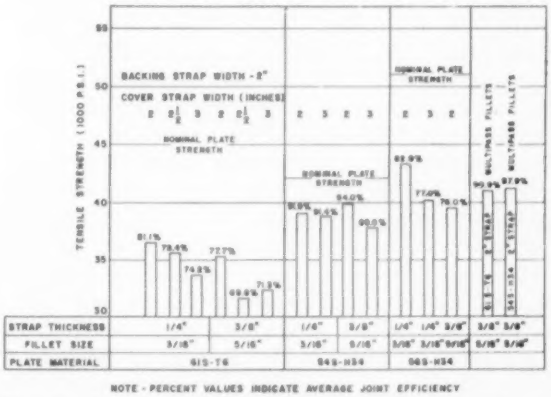
61S-T6 and 54S-H34 were obtained by a combination of straps of equal width and fillets deposited with multipass technique.

The yielding phenomena of prime plate and welded specimens for plain and strapped butt joints in the four alloy compositions are presented as Figs. 12, 13, 14 and 15. It is apparent that not only is the yield strength of the group of welded specimens lower than that of the parent plate in all cases and for each alloy, but there is a marked difference in their general yielding characteristics. It is to be noted that in all compositions the proportional limits and yield strengths are lowest for the single-strap butt joints.

The results of the hardness surveys across representative transverse weld sections are presented graphically as Figs. 16 and 17.

The survey of the weld section in 61S-T6 alloy indicates a zone just outside the fusion line that is harder than the weld metal. Still farther from the fusion line there is a softer zone. Thus, the survey indicates rather sharp changes in hardness at several points.

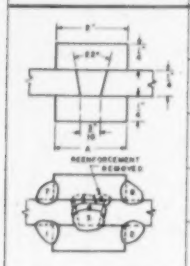
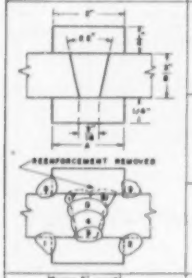
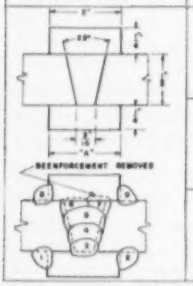
In contrast, Fig. 17 indicates a relatively gradual change from the softer weld metal to the original hardness of the 54S-H34 plate material.



NOTE - PERCENT VALUES INDICATE AVERAGE JOINT EFFICIENCY

Fig. 11 Strength and efficiency of welded aluminum double-strapped double-bevel single-vee butt joints $^1/_2$-in. plate material based on transverse tensile properties

Table 4—Transverse Physical Properties of Aluminum Alloy Double-Strap Butt Welds Helium Shielded

JOINT DESIGN	WELDING POSITION	STRAP WIDTH "A"-IN	FILLET SIZE IN	ALUMINUM ALLOY 52S-H34 (1) ULTIMATE STRENGTH P.S.I. (4)	52S-H34 (1) ELONGATION PERCENT (5)	52S-H34 (1) LOCATION OF FRACTURE	54S-H34 (2) ULTIMATE STRENGTH P.S.I. (4)	54S-H34 (2) ELONGATION PERCENT (5)	54S-H34 (2) LOCATION OF FRACTURE	56S-H34 (3) ULTIMATE STRENGTH P.S.I. (4)	56S-H34 (3) ELONGATION PERCENT (5)	56S-H34 (3) LOCATION OF FRACTURE	61S-T6 (1) ULTIMATE STRENGTH P.S.I. (4)	61S-T6 (1) ELONGATION PERCENT (5)	61S-T6 (1) LOCATION OF FRACTURE
	O	2	3/16	-	-	-	40800	7.3	BASE METAL	46000	7.8	BASE METAL	34900	5.8	BASE METAL
	H	2	3/16	-	-	-	39300	6.0	BASE METAL	50100	7.0	BASE METAL	-	-	-
	O	2-1/2	3/16	-	-	-	-	-	-	-	-	-	33500	7.5	BASE METAL
	H	2-1/2	3/16	-	-	-	-	-	-	-	-	-	33300	1.7	BASE METAL
	O	3	3/16	-	-	-	39600	7.5	BASE METAL	46200	7.8	BASE METAL	31600	7.0	BASE METAL
	O	2	3/16	-	-	-	40100	14.0	BASE METAL	48900	14.7	WELD METAL	36300	1.6	BASE METAL
	O	2-1/2	3/16	-	-	-	-	-	-	-	-	-	33500	1.0	BASE METAL
	O	3	3/16	34100	4.0	BASE METAL	39300	10.5	BASE METAL	44700	9.0	BASE METAL	36700	1.7	BASE METAL
	O	2	3/16	-	-	-	38600	9.5	BASE METAL	43100	10.2	BASE METAL & WELD METAL	36500	2.0	WELD METAL
	O	2-1/2	3/16	-	-	-	-	-	-	-	-	-	35300	2.5	WELD METAL
	O	3	3/16	-	-	-	38400	7.8	BASE METAL	40000	3.5	BASE METAL & WELD METAL	33400	1.7	WELD METAL

NOTES - 1. ALUMINUM ALLOY 43S FILLER METAL
2. " " 54S " "
3. " " 56S " "
4. AVERAGE OF THREE SPECIMENS
5. " " " " ELONGATION TAKEN IN 2" ACROSS FRACTURE

DISCUSSION

In the case of a precipitation-hardened alloy, the effect of the precipitation hardening is materially reduced by the heat of welding. Some area within the heat-affected zone will approach the annealed state of the base plate material. In the zone in the base metal near the fusion line the precipitation-hardening material may be reabsorbed into solid solution. The zone will then harden to various levels on aging. The result will be a harder zone near the fusion line and an over-aged zone at a greater distance from the fusion line.

There is no indication of a harder area outside the fusion lines in the welds in stabilized alloy 54S-H34, as indicated by Fig. 17. In contrast to welds in 61S-T6, the zones outside the fusion lines are softened. There is a gradual transition to the hardness of the parent plate. The joint is free of the sharp changes in hardness indicated for 61S-T6 by Fig. 16.

A comparison of the nominal tensile properties of the base plate and corresponding weld metal is given below:

Type of material	*Yield strength, psi*	*Tensile strength, psi*	*Elongation % in 2 in.*
A161S-T6 Plate	41,000	45,000	22
43S Weld Metal	12,400	25,100	14
A152S-H34 Plate	30,000	37,000	18
43S Weld Metal	12,400	25,100	14
A154S-H34 Plate	35,000	42,000	18
54S Weld Metal	16,000	30,600	22
A156S-H34 Plate	37,000	53,000	18
56S Weld Metal	21,000	40,500	27

Since all the weld metals are weaker than the base metals in which they were deposited, the tensile specimens were tested without removal of the weld reinforcement. It would appear that removing the weld reinforcements would have resulted in more failures through the weld metals at lower tensile values.

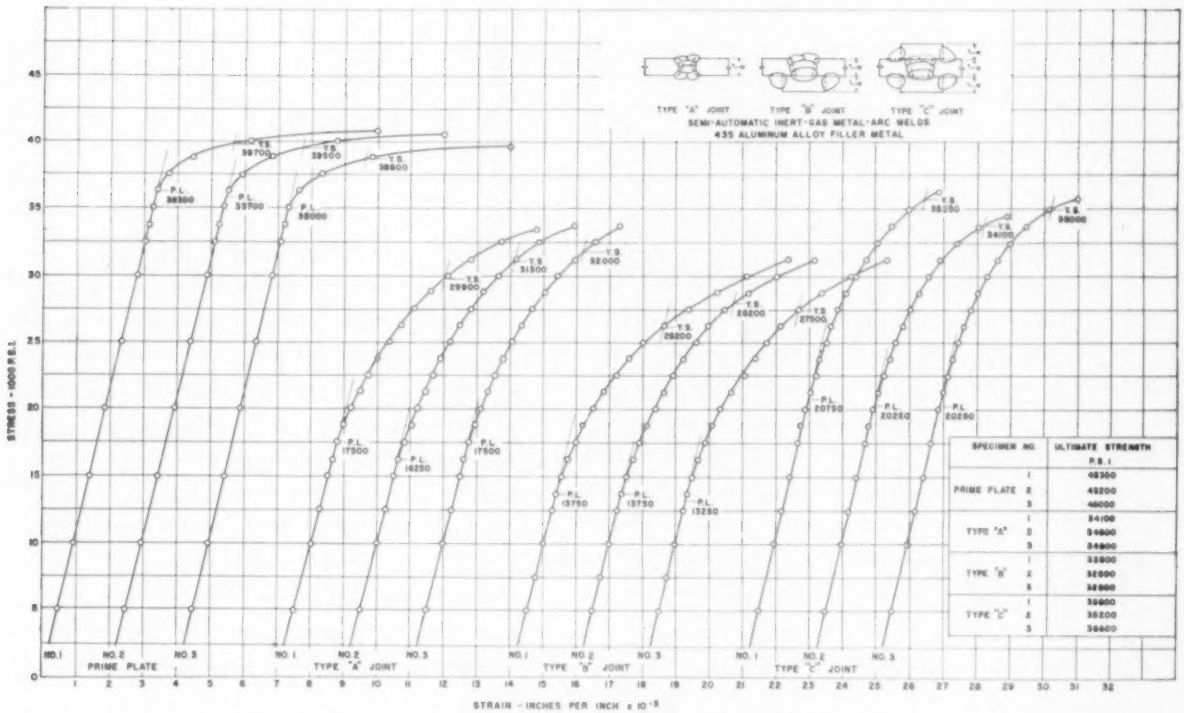
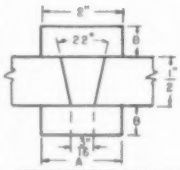
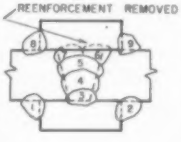
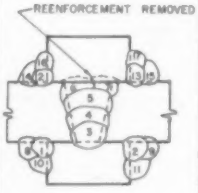


Fig. 12 Stress-strain curves for 61S-T6 aluminum alloy prime plate and welded assemblies

Table 5—Transverse Physical Properties of Aluminum Alloy Double-Strap Butt Welds Helium Shielded

JOINT DESIGN	WELDING POSITION	STRAP SIZE		FILLET SIZE IN.	ALUMINUM ALLOY								
					54S-H34 (3)			56S-H34 (3)			61S-T6 (3)		
		WIDTH "A"- IN.	THICK. "B"- IN.		ULTIMATE STRENGTH P.S.I. (4)	ELONGATION PERCENT (5)	LOCATION OF FRACTURE	ULTIMATE STRENGTH P.S.I. (4)	ELONGATION PERCENT (5)	LOCATION OF FRACTURE	ULTIMATE STRENGTH P.S.I. (4)	ELONGATION PERCENT (5)	LOCATION OF FRACTURE
	0	2	1/4	3/16	38600	9.5	BASE METAL	43100	10.2	BASE METAL & WELD METAL	36500	2.0	WELD METAL
	0	2-1/2	1/4	3/16	-	-	-	-	-	-	33300	2.9	WELD METAL
	0	3	1/4	3/16	38400	7.8	BASE METAL	40000	3.5	BASE METAL	33400	1.7	WELD METAL
	0	2	3/8	5/16	39500	8.5	BASE METAL	39500	9.3	BASE METAL	33000	2.3	BASE METAL
	0	2	3/8	5/16 (6)	41100	15.1	BASE METAL	-	-	-	40900	1.3	WELD METAL
	0	2-1/2	3/8	5/16	-	-	-	-	-	-	31400	0.5	BASE METAL
MULTI-PASS FILLETS SEE NOTE (6)	0	3	3/8	5/16	37400	8.2	BASE METAL	-	-	-	32100	2.2	BASE METAL

NOTES— 1. ALUMINUM ALLOY 435 FILLER METAL
2. " " 545 " "
3. " " 565 " "
4. AVERAGE OF THREE SPECIMENS
5. " " " " . ELONGATION TAKEN IN 2" ACROSS FRACTURE
6. FILLETS DEPOSITED USING MULTI-PASS SEQUENCE

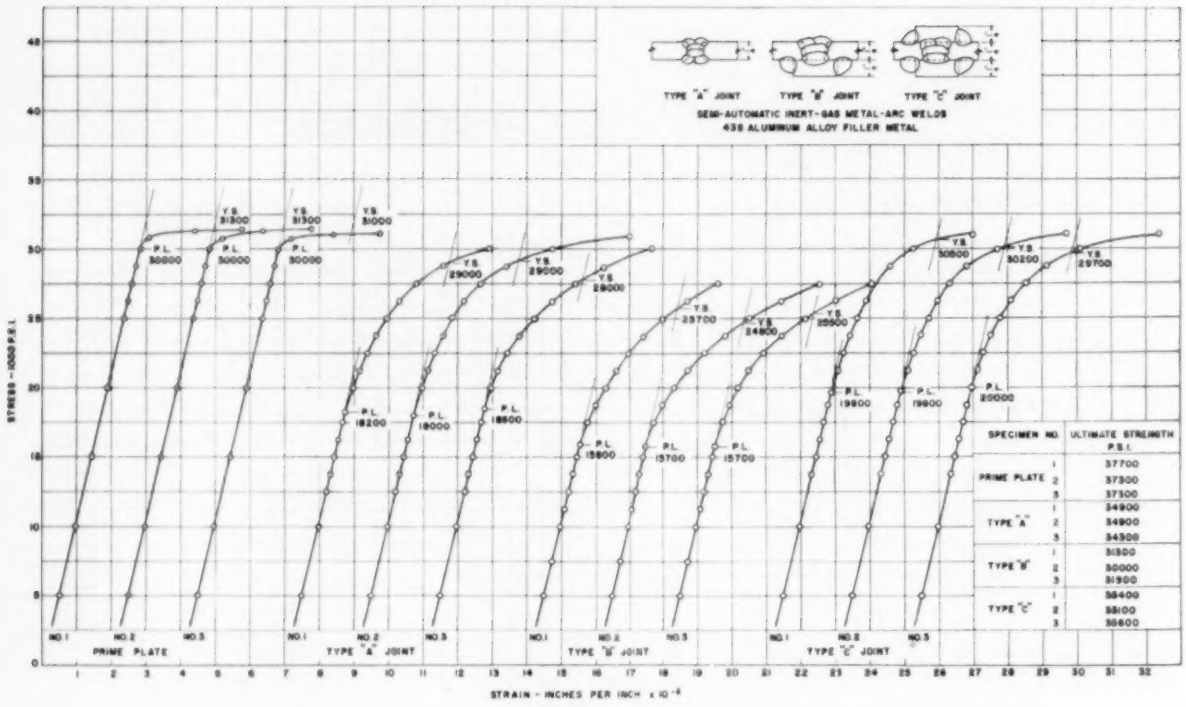


Fig. 13 Stress-strain curves for 52S-H34 aluminum alloy prime plate and welded assemblies

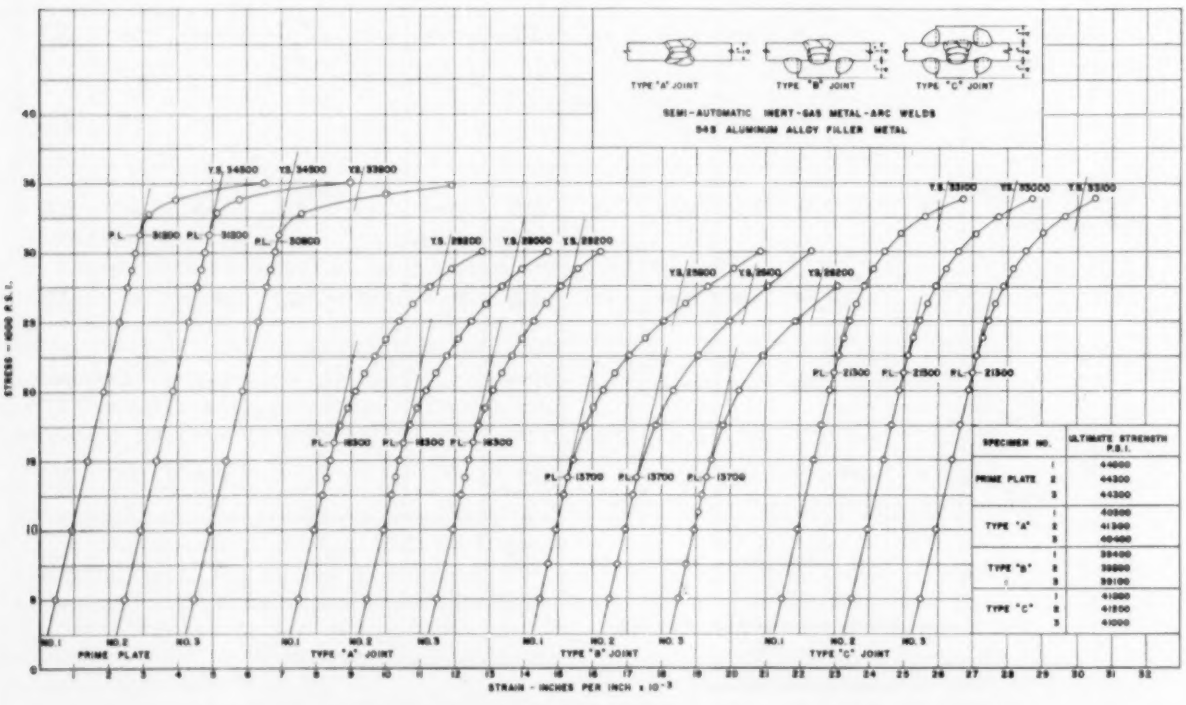


Fig. 14 Stress-strain curves for 54S-H34 aluminum alloy prime plate and welded assemblies

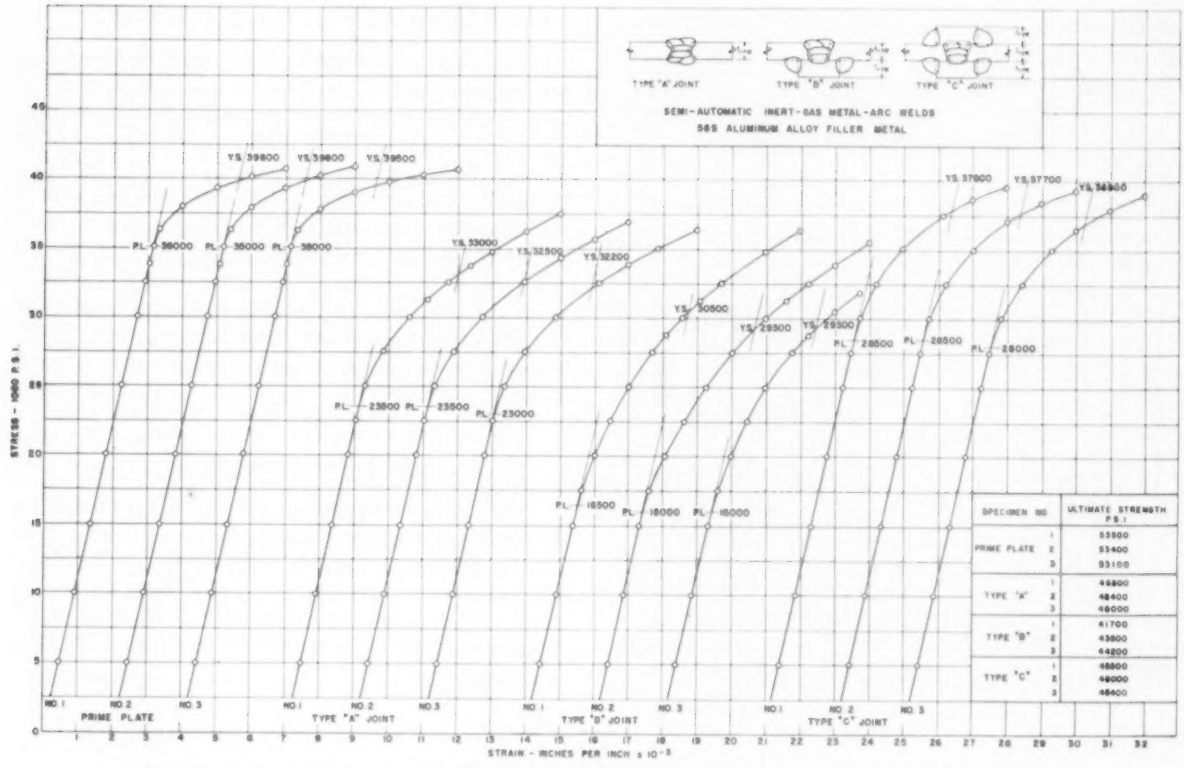


Fig. 15 Stress-strain curves for 56S-H34 aluminum alloy prime plate and welded assemblies

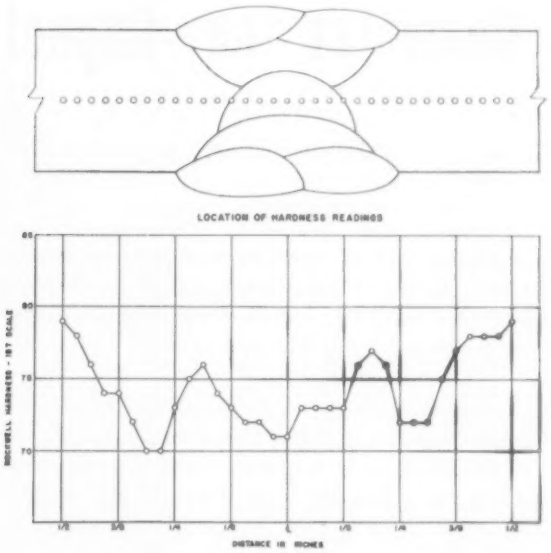


Fig. 16 Hardness survey of butt weld 1/2-in. AL 61S-T6 plate and 1/16-in. diam 43S filler metal

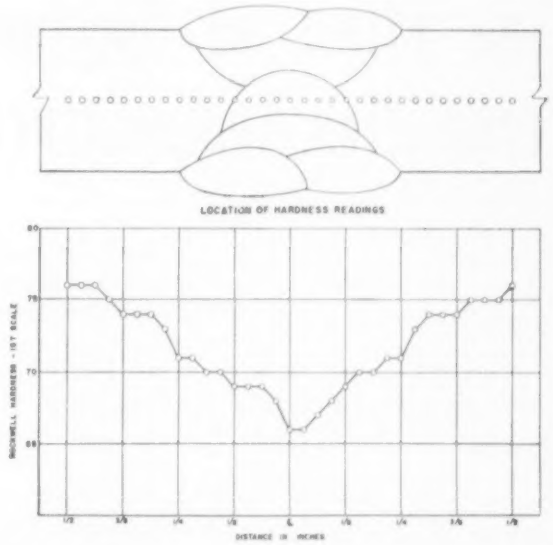


Fig. 17 Hardness survey of butt weld 1/2-in. AL 54S-H34 and 1/16-in. diam 54S filler metal

CONCLUSIONS

From the data presented herein, it may be concluded that:

(*a*) The stabilized alloys show higher joint efficiencies in the welded condition because they are less affected by the heat of welding than the precipitation-hardened alloys.

(*b*) Stabilized alloy 54S-H34 is the least affected by the heat of welding.

(*c*) Single-strap butt joints exhibit lower proportional limits and yield strengths than plain or double-

strap butt joints in all the alloys tested; however, some gain is made in the tensile properties of butt joints in the precipitation-hardened alloy by the use of straps.

(*d*) There is no significant gain in the tensile strength of butt joints in the stabilized alloys by the addition of straps.

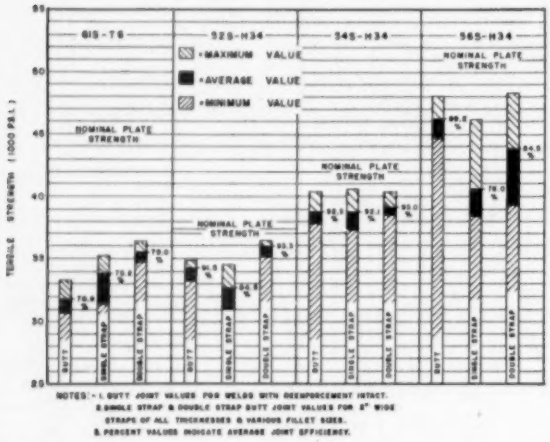


Fig. 18 Summary of joint performance over-all average of tensile values (all plate thicknesses)

SUMMARY OF CONCLUSIONS

A summary of the performance of the three types of welded joints in the four alloys is presented as Fig. 18. The percent values beside the bars are the average joint efficiencies for each alloy material and type of joint. It is again apparent that alloy 61S-T6 is affected by the heat of welding to the greatest extent, 54S-H34 the least, and 56S-H34 intermediate. Further, welded joints in 54S-H34 are the least affected by the geometry of the joint. Based on welding characteristics established by the results presented herein, the 54S-H34 aluminum alloy would appear to give the better performance in properly designed welded structures.

ACKNOWLEDGMENT

The authors wish to express their appreciation for the encouragement and assistance received from J. E. McCambridge, Superintending Engineer, Industrial Test Laboratory, Philadelphia Naval Shipyard, and to R. G. Lull, R. L. Beyer, Jr., Salvatore J. Alesi and J. W. Angeny for their assistance in the preparation of tables and figures.

The Effect of Specimen Geometry on Impact Transition Temperature

A statistical analysis of the effect of specimen size and notch geometry on the impact transition temperature of SAE 1020 steel. Relationship between the Charpy V and Keyhole notches

by R. S. Zeno and J. L. Dolby

INTRODUCTION

THIS investigation was made to determine the relationship, if any, between Charpy impact bar size and notch geometry on the impact transition temperature of SAE 1020 steel. The general plan was to break a series of V-notch and Keyhole notch Charpy bars in which all dimensions were held constant with the exception of breadth. The breadth dimensions were standard, one-half and one-quarter size. Impact transition temperatures were determined by three methods; namely, absorbed energy, fracture appearance and contraction of area under the notch.

A statistical study was made relating the specimen size and notch geometry to the transition temperatures.

MATERIAL

The SAE 1020 steel used in this investigation was hot rolled $^1/_2$-in. plate, normalized at 1700° F, one hour, and air cooled. This treatment produced a microstructure of elongated grains of ferrite and pearlite with an ASTM grain size of 5–6.

The composition of the SAE 1020 steel in weight percent was as follows: C 0.20, Mn 0.83, P 0.020, S 0.040 and Si 0.05.

R. S. Zeno and J. L. Dolby are connected with the General Electric Co., Schenectady, N. Y.

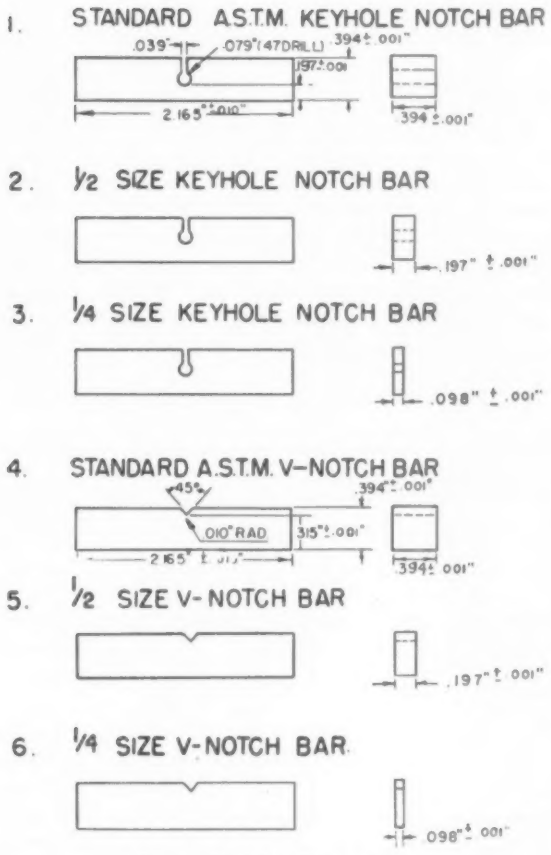


Fig. 1 Modified Charpy bars

SPECIMENS

The test bars used in this investigation for determining impact transition temperatures are shown in Fig. 1. With the exception of breadth all other dimensions were the same as standard ASTM Charpy V and Keyhole notch bars. Test bars were broken in groups of three taken from the same location in the plate. In all cases the notch was machined perpendicular to the plate surface. The specimen length was at 90° (transverse) to the rolling direction. Hereafter, all the test bars will be referred to as one-quarter, one-half and full size.

IMPACT TESTING

The impact testing was performed on two machines: One the standard Tinius Olsen Impact Tester with a maximum capacity of 264 ft-lb with a 4.4 ft drop and striking velocity of 16.8 fps. All the testing done with this machine was at the 2 ft fall setting or 120 ft-lb capacity with a striking velocity of 11.3 fps.

The other impact tester used for the lion's share of the work was a Baldwin-Southwark Corp. machine built by O. S. Peters, Washington, D. C., based on a design by the Bell Telephone Laboratories, Inc. The maximum capacity of this machine was 16 ft-lb. at a 2 ft fall with a striking velocity of 11.3 fps.

Testing temperatures were obtained as follows:

1. −100° to 0° C—Cold box with liquid nitrogen as the coolant.

2. Room temperature (+22° C) to + 100° C—Low temperature oven.

For the −100° to 0° C range the specimens were removed from the cold box after the liquid nitrogen had evaporated and the desired temperature was reached.

The time necessary to remove the specimen from the container, place on the supports, and break, varied from four to five seconds, with the average time close to five seconds.

RESULTS AND DISCUSSION

The results are summarized in Tables 1, 2, and 3, Figs. 2 through 8, and Appendix I. The curves from which the transition temperatures were determined and tabulated (Table 1) were not included in this paper in order to conserve space. Since one point at each temperature was plotted rather than the average of several points, a total of fifty-four (54) curves were required. Included, however, were the data from which these curves were plotted (Tables 2 and 3).

Figures 2 through 7 were included only to show the general shape of the curves. The points plotted in these curves are averages of three test results at each temperature (Tables 2 and 3). The indicated transition temperatures, however, were not used in the calculations in Appendix I.

The energy transition temperatures given in Table 1 were determined as the 50% of maximum energy on the curves of impact energy versus temperature.

Table 1—Comparison Between Energy Transition, Fracture Appearance Transition and Contraction of Area Under the Notch Transition Temperatures

Material	*Size bar*	*Notch*	*Energy transition temperature, ° C*	*Fracture appearance transition temperature, ° C*	*Contraction of area under the notch transition temperature, ° C*
SAE 1020	1/4	Keyhole	−70, −102, −87	−45, −56, −50	−72, −134, −142
	1/2	Keyhole	−20, −20, −21	−21, −18, −18	−25, −19, −22
	Full	Keyhole	−16, −18, −2	−18, +5, +5	−15, −21, −12
	1/4	V	−26, −24, −32	−24, −24, −24	−27, −26, −24
	1/2	V	−1, −10, −13	−9, −9, +14	−10, −12, −12
	Full	V	+5, +3, +1	+24, +21, +21	−3, +2, +3

The fracture appearance transition temperatures given in Table 1 were determined as the 50% ductile fracture from the plots of percent fibrous fracture vs. temperature. All fracture surfaces were examined under a low power microscope.

The contraction of area under the notch (deformation) transition temperatures given in Table 1 were determined as the 50% of maximum contraction on the curves of percent contraction vs. temperature.

The contraction of area under the notch measurements were made with a thread dial micrometer with the fixed anvil and the movable point both cone shaped. A magnetic fixture was used for holding the broken bars in position during the measurement. The actual values were calculated as follows:

$$\text{Percent Contraction of area under the notch} = \left(\frac{\text{Original bar thickness (0.394 in. in all cases)} - \text{Contracted bar thickness under notch}}{\text{Original bar thickness}} \right) \times 100$$

As the energy required to break the sub-size specimens was found to be less than 16 ft-lb it was decided to use the small Baldwin-Southwark tester for reasons of greater accuracy within this lower impact range. All specimens which required more than 16 ft-lb to break were tested on a Standard Tinius Olsen machine. In either case a striking velocity of 11.3 fps was maintained.

The comparison between the energy and fracture ap-

Table 2—SAE 1020 Steel, 1/4, 1/2 and Full-Size Keyhole Notch Charpy Bars

Temp. °C	*Energy ft-lb*	*Average ft-lb**	*Fracture appearance, % fibrous*	*Average, %**	*Contraction of area under the notch, %*	*Average %**
			1/4-size bars			
−100	0.2, 3.3, 2.6	2.0	0, 7, 5	4	2.0, 18.4, 23.5	14.6
− 50	4.2, 4.4, 4.7	4.4	40, 60, 50	50	27.5, 23.5, 28.6	26.5
0	4.4, 5.3, 5.7	5.1	99, 85, 95	93	30.6, 26.5, 29.6	28.9
+ 22	5.5, 5.8, 6.2	5.8	100, 100, 100	100	31.6, 29.6, 30.1	30.4
+ 50	5.8, 5.8, 5.2	5.6	100, 100, 100	100	33.7, 25.5, 32.6	30.6
+100	5.4, 5.5, 5.3	5.4	100, 100, 100	100	32.6, 29.6, 30.6	30.9
			1/2-size bars			
−100	0.4, 0.5, 0.5	0.5	0, 0, 0	0	1.0, 1.5, 1.5	1.3
− 50	1.0, 1.7, 1.2	1.3	5, 5, 5	5	2.0, 3.1, 2.0	2.4
0	10.2, 11.2, 11.8	11.1	80, 75, 75	77	21.4, 21.7, 21.8	21.6
+ 22	12.4, 14.1, 14.2	13.6	95, 95, 95	95	22.4, 22.4, 25.0	23.3
+ 50	13.3, 13.4, 13.9	13.5	99, 95, 98	97	23.2, 23.2, 23.8	23.4
+100	9.8, 11.8, 13.7	11.8	100, 100, 100	100	21.3, 25.4, 22.6	23.1
			Full-size bars			
−100	1.0, 1.0, 1.0	1.0	0, 0, 0	0	0.8, 0.8, 0.8	0.8
− 50	2.0, 2.0, 2.0	2.0	2, 3, 3	3	0.8, 1.0, 1.0	0.9
0	16.0, 18.0, 14.0	16.0	70, 60, 60	63	8.9, 10.9, 7.3	9.0
+ 22	21.0, 20.0, 27.0	22.7	100, 100, 100	100	9.4, 9.9, 8.6	9.3
+ 50	22.0, 22.0, 25.0	23.0	100, 100, 100	100	9.9, 9.6, 10.7	10.1
+100	20.0, 21.0, 24.0	21.7	100, 100, 100	100	10.4, 9.6, 11.4	10.5

* These average values were used to plot the transition curves in Figs. 2 through 7. The indicated transition temperatures, however, were not used in the Calculations in Appendix I.

Table 3—SAE 1020 Steel, 1/4, 1/2 and Full Size, Notch Charpy Bars

Temp., °C	*Energy ft-lb*	*Average, ft-lb**	*Fracture appearance, % fibrous*	*Average, %**	*Contraction of area under the notch, %*	*Average, %**
			1/4-size bars			
−100	0.3, 0.4, 0.4	0.4	0, 0, 0	0	2.1, 2.1, 1.0	1.7
− 50	1.9, 1.1, 1.8	1.6	2, 3, 3	3	5.2, 7.1, 7.2	6.5
0	6.5, 8.5, 7.9	7.6	95, 97, 99	97	28.6, 24.5, 25.3	26.1
+ 50	8.1, 9.5, 7.7	8.4	100, 100, 100	100	28.9, 25.8, 27.6	27.4
+100	7.2, 8.6, 7.5	7.8	100, 100, 100	100	29.6, 30.6, 31.6	30.6
			1/2-size bars			
−100	0.5, 0.7, 0.7	0.6	0, 0, 0	0	0.5, 0.5, 0.5	0.5
− 50	1.7, 0.8, 1.1	1.2	0, 0, 0	0	1.5, 1.5, 1.5	1.5
0	8.6, 11.1, 12.0	10.6	60, 60, 30	50	11.2, 12.2, 12.7	12.0
+ 50	17.0, 16.0, 17.0	16.7	100, 100, 100	100	14.1, 14.6, 15.2	14.6
+100	12.0, 14.0, 18.0	14.7	100, 100, 100	100	17.1, 17.7, 17.2	17.3
			Full-size bars			
−100	1.3, 1.4, 1.4	1.4	0, 0, 0	0	0.3, 0.2, 0.3	0.3
− 50	3.8, 2.2, 3.4	3.1	0, 0, 0	0	0.8, 0.5, 0.8	0.7
0	16.0, 16.0, 16.0	16.0	10, 20, 20	17	5.6, 5.1, 5.1	5.3
+ 50	35.0, 35.0, 34.0	34.7	99, 99, 99	99	10.0, 9.4, 10.7	10.0
+100	36.0, 35.0, 34.0	35.0	100, 100, 100	100	10.4, 10.2, 10.7	10.4

* These average values were used to plot the transition curves in Figs. 2 through 7. The indicated transition temperatures, however were not used in the Calculations in Appendix I.

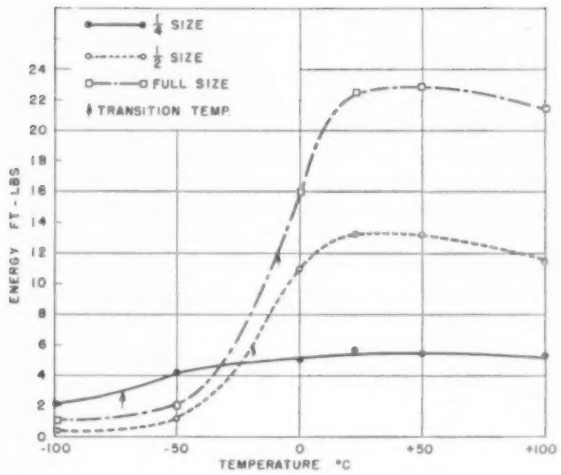


Fig. 2 Energy transition curves SAE 1020 keyhole notch

pearance transition temperatures for the same specimen size and notch in Table 1 shows that in a few cases the two transition temperatures do agree. The agreement, however, is in general, quite poor for the two methods of determining transition temperature.

The contraction of area under the notch transition temperatures for the same specimen size and notch given in Table 1 were in general lower than the energy and fracture appearance transition temperatures. Stout and McGeady[1] have shown for ship plate steel that the transition temperatures determined by measuring the contraction of area under the notch were in most cases considerably lower than those determined by energy absorption or fracture appearance. The former was termed the lower or ductility transition while the latter two were referred to as the upper or fracture transition. Stout and McGeady[1] also discussed the probability that contraction of area under the notch was a measurement of the ductility of the steel before cracking becomes extensive. On the other hand, energy after maximum load and fracture appearance reflect the behavior of the steel during propagation of the crack across the section.

Vanderbeck and Gensamer[2] have thoroughly discussed these concepts in their paper on the evaluation of notch toughness.

Harris et al.[3] have shown transition curves with an upper and lower transition temperature for several mild carbon steels.

From Table 1 (Fig. 8) it can be seen that for SAE 1020 steel and notch conditions investigated the transition temperature determined by the three methods all shift to lower temperatures with a decrease in specimen size. This confirms the findings of Buffum[4] who showed a decrease in the energy and fracture appearance transition temperatures as the cross-sectional area of standard V-notch Charpy bars was decreased. The material investigated by Buffum[4] was SAE 3140 steel heat treated to produce a structure consisting of 95% tempered bainite and 5% tempered martensite.

STATISTICAL ANALYSIS

The first problem in analyzing the test data in this investigation was that of determining the transition temperature from the 54 tests made on each set of samples. This could have been done by any of several methods of curve fitting to derive the functional form of the relationship with temperature and then calculating the inflection point of the curve. The method of least squares, for instance, used with a third degree polynomial would probably have proved quite efficient. However, with such a mass of data and a measurable test error it was thought that the standard means of plotting the data and fairing the curve would be sufficiently accurate. Thus the transition temperatures were estimated from the faired curves by methods previously discussed and analyzed. The resulting test error seemed to conform rather closely with past experience and hence this method was accepted.

Detailed calculations for the SAE 1020 steel will be included in Appendix I. Looking at Table 1, it can be seen that every possible combination of the three different sized bars, the two types of notch, the three sets of data, and the three means of estimating the transition temperature were investigated. An experiment of this sort is generally referred to in statistics as a factorial experiment due to the fact that the total number of test values (transition temperatures) can be calculated from the product of the number of possibilities for each of the factors (in this case, $3 \times 2 \times 3 \times 3$). One of the most powerful statistical tools for estimating the significance of the factors on the measured variable in such a case is the analysis of variance. Any recent statistical

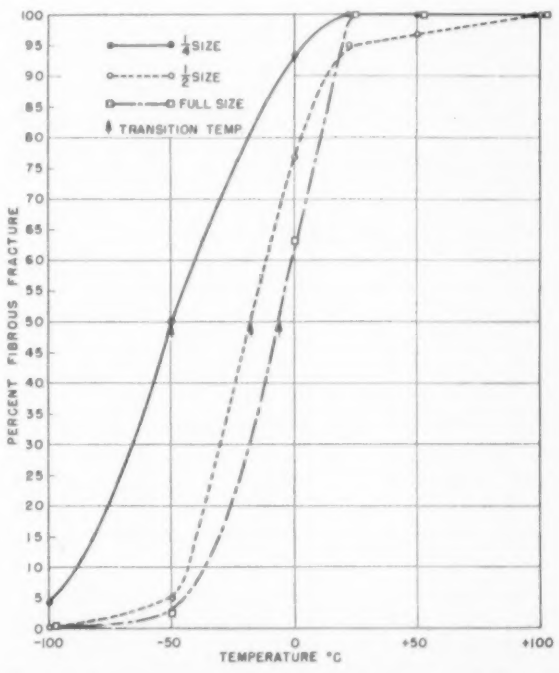


Fig. 3 Fracture appearance transition curves SAE 1020 keyhole notch

text will provide the mechanics for the use of this tool, but since its use has been rather restricted in engineering applications the calculations are carried out in some detail here (Appendix I).

The first step in such an analysis is to group the data in several blocks so that the pattern of variation can be brought out more clearly. For convenience, this is normally done in terms of totals rather than averages. Hence, in Schedule A, the Type-Notch block summarizes the results of the tests made using the two different notches and the three means of estimating the temperature. The first figure, −356, is the total of the 9 tests made using the keyhole notch and the energy estimate of the transition temperatures. Of course, these tests were made on three different sized bars and it may seem artificial to average them out since the large bars might react quite differently with the keyhole notch than the small bars (this indeed proved to be the case), but each

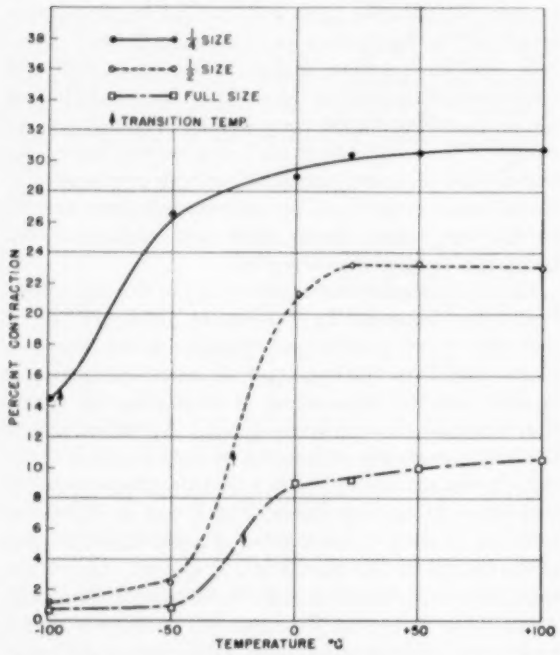


Fig. 4 Contraction under notch transition curves SAE 1020 keyhole notch

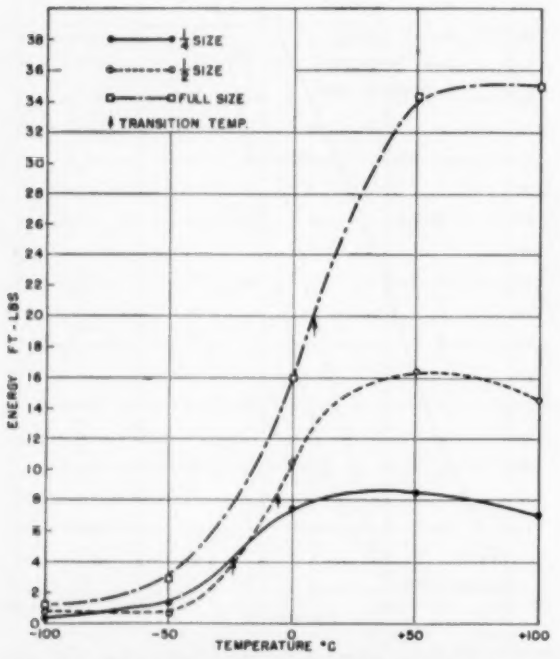


Fig. 5 Energy transition curves SAE 1020 V notch

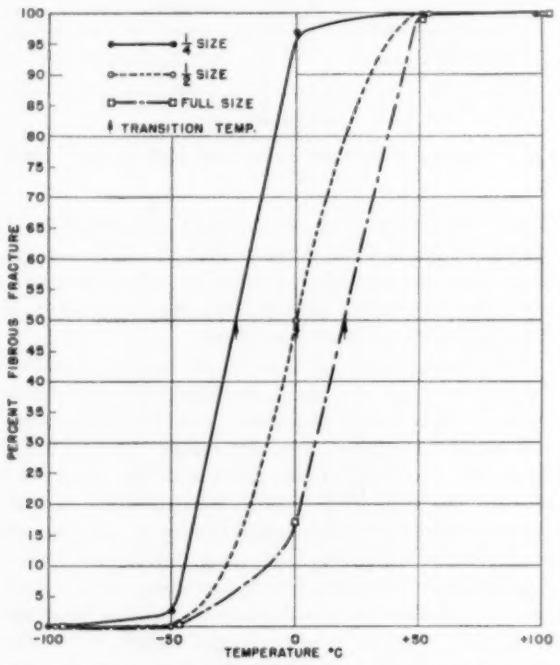


Fig. 6 Fracture appearance transition curves SAE 1020 V notch

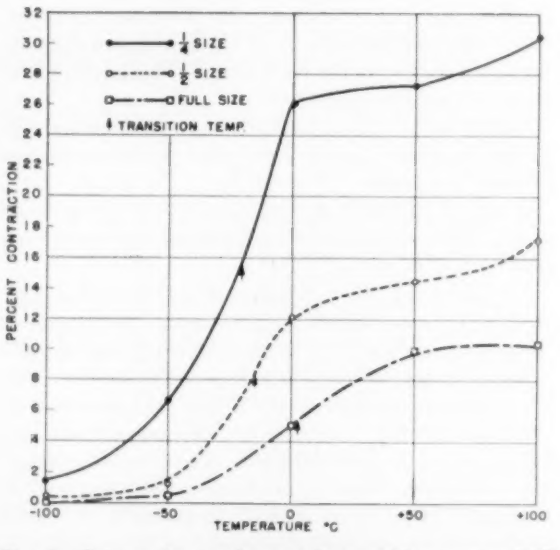


Fig. 7 Contraction under notch transition curves SAE 1020 V notch

combination is weighted equally in this respect and it is possible to measure interactions of this sort separately.

An investigation of these three blocks would seem to indicate that the V notch in general gives a higher transition temperature than the keyhole; that the fracture appearance, energy absorption and contraction of area under the notch give successively lower estimates; and that the transition temperature seems to increase with specimen size. Moreover, these effects seemed to be independent of each other in the range examined except that the pattern of variation with size for the keyhole notch is quite different from that with the V notch. The transition temperature seems to increase linearly with size when the V notch is used but the increase tapers off quite rapidly when the keyhole notch is used (Fig. 8).

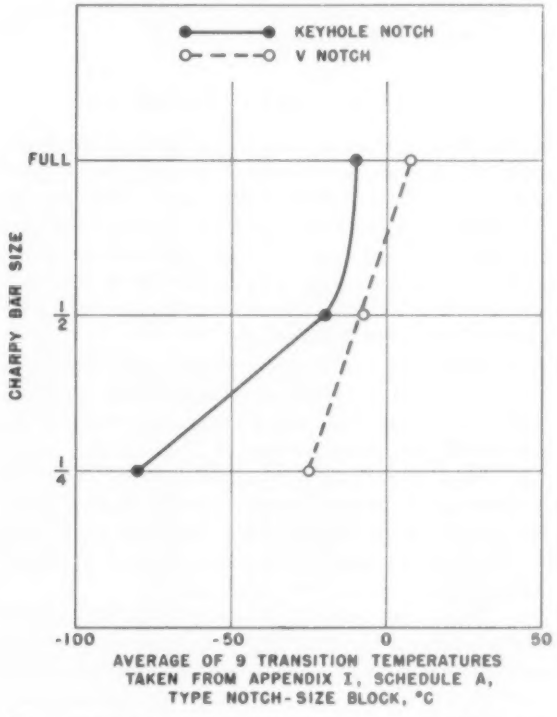


Fig. 8 Charpy bar size and type notch vs. transition temperature

These effects seem quite marked when the data are examined in this manner, but it is highly desirable to be able to show that they are sufficiently large to preclude the possibility that experimental error alone provided them. This is done by breaking down the total variation—as expressed by the sum of the squares of the deviations of each of the test values from the grand mean. The portion of this variation due to the different methods of estimating the transition temperature, for instance, can be found by calculating the sum of the squares of the deviations of the three means found for these three methods from the grand mean and multiplying by the number of values in each mean to correct for the deflation due to the averaging process. This can be expressed algebraically as follows:

$$SS_T = lmr \sum_{i=1}^{n} (\bar{X}_i - \bar{\bar{X}})^2$$

where, in this case:

SS_T = sum of squares of three methods of determining transition.
l = no. of notch types.
m = no. of bar sizes.
n = no. of means of determining transition temperature.
r = no. of replications.
$\bar{X}_i$ = average (over the l notch types, m bar sizes, and r replications) of the i^{th} ($i = 1, 2, 3$) methods of determining transition temperature.
$\bar{\bar{X}}$ = grand mean of all 54 transition temperatures.

For convenience in calculation, this is usually written in the equivalent form:

$$SS_T = \frac{1}{lmnr}\left[n \sum_{i=1}^{n} T_i^2 - T_G^2\right]$$

where:

T_i = total (over the l notch types, m bar sizes, and r replications) of the i^{th} ($i = 1, 2, 3$) method of determining transition temperature.
T_G = grand total of all 54 transition temperatures.

Any interaction between two of the factors is found by finding the sum of the squares of the deviations of the values in the block for those two variables and subtracting the sum of the squares of the deviations due to each of the factors.

In general, each of these sums of squares will be different from zero even if the alleged source of variation has no real effect upon the measured variable for the simple reason that, in general, there is some experimental error in the system. In order to obtain an estimate of this error so that those accounted for sources of variation which have an effect upon the measured variable may be separated from those which do not, we calculate the total variation (sum of squares) and subtract from it each of the sum of squares previously found. The remainder is usually called the "residual" or "error" sum of squares. Before any comparisons can be made with this residual sum of squares, it is necessary to put all the sums of squares on the same basis and this is done by dividing each by the number of comparisons (or degrees of freedom, in statistical parlance) involved in it to obtain a "mean" square. For instance, one comparison can be made between the values found using the keyhole and V notches and this sum of squares is divided by one. In general, there will be one less comparison than there are values to be compared (since all the comparisons are internal). As for the comparisons possible for an interaction sum of squares, an investigation of the type-notch block will show that there are six values, hence five internal comparisons, one of which was used in comparing the keyhole to the V notch and two more of which were used in comparing the three means of estimating the

transition temperature; consequently, there are two comparisons left for the interaction.

We have already noted that each of these sums of squares (and hence the mean squares) will be different from zero, if for no other reason than the inherent experimental error present in the system. The important question remaining is whether there is some other force acting in the system to make the mean square under consideration larger than could be expected if only experimental error were involved. The obvious step here is to compare each of the mean squares for which there is some reason to suspect that an exterior force could have enlarged the residual mean square which presumably is free of all but experimental error. This comparison is best made by taking the ratio of the former to the latter (known as the F value). If this ratio is much larger than unity there is reason to believe that the mean square in the numerator is indeed too large.

It is at this point that the analyst can take advantage of probability theory. If we can assume that the deviations due to error follow the Gaussian or "normal" curve, it is possible to derive mathematically the distribution of the ratio of two mean squares of samples drawn at random from such a population. This distribution has been tabulated by Hoel[5] and others for a large number of possible combinations of sample sizes or "degrees of Freedom" for each mean square. The accepted procedure is to compare this ratio to a ratio that would occur by chance (if both mean squares are due to error variation only) perhaps 5% or 1% of the time. It is these 5% and 1% "chance" values of the ratio that are tabulated in Schedule C and in turn used in the present work.

Using this criterion, we have separated out the significant causes of variation in the system. These are the three main variables—method of determining transition temperature, type notch and bar size—which all give a higher ratio (F value) than would be expected 1% of the time—and previously mentioned interaction between notch type and size which gave a ratio (F value) that would occur less than 5% of the time. It is also possible to make use of the residual or error mean square as a quantitative measure of the experimental error. If we can assume that the original estimates of the transition temperature follow the Gaussian law of error, then the square root of the error mean square for the SAE 1020 (in this case $\sqrt{179} = 13.4°$ C) gives a numerical value of the dispersion of the values. That is, it gives us an idea of how close a particular value (in this case, a transition temperature determined from one set of 6 temperature-strength points) is to the true value. Since the error mean square was derived from the data it is also subject to some error. Hence, we must find the joint distribution of the error of a particular measurement and the uncertainty associated with that error. This distribution (t) has been tabulated by Hoel.[6] In this case we have 40 degrees of freedom in the estimate of the error and from the table, the appropriate t factor is somewhere between 2.750 and 2.576 for 99% confidence that the true value is included in the interval $\pm t\sqrt{MSe}$ where $\sqrt{MSe}$ is the square root of the error mean square. The exact value for t is 2.71. For this case the interval is $\pm 2.71\sqrt{179}$ or $\pm 36.3°$ C.

These statistical analyses have indicated that the impact transition temperature for a ferritic steel will change with the type notch, bar size and method used to determine it. There was also strong evidence to suggest that the variation of transition temperature with bar size will depend upon the type notch used.

Finally, the experimental error observed would lead us to believe that a given test on ferritic materials under conditions similar to those imposed in this investigation would provide one with a transition temperature correct to $\pm 36°$ C. Under other conditions, e.g. a change in notch geometry, bar size and method of determining the transition temperature, the figure of $\pm 36°$ C could conceivably be exceeded.

SUMMARY AND CONCLUSIONS

The effect of Charpy impact bar size and notch geometry on the impact transition temperature of SAE 1020 steel was determined statistically. This was accomplished by using a series of $^1/_4$, $^1/_2$ and full size bars with Keyhole and V notches. The transition temperatures were determined for this steel by three methods, namely; absorbed energy, fracture appearance and contraction of area under the notch.

The following conclusions appear to be warranted:

1. The impact transition temperatures for SAE 1020 steel increased linearly with specimen size for the V notch Charpy bars investigated.

2. The impact transition temperature for SAE 1020, Keyhole notch Charpy bars also increased with specimen size, however, non-linearly. This was due in part to the interaction observed between the notch geometry and bar size.

3. Ninety-nine percent of the time the true transition temperature of SAE 1020 (and probably similar plain low-carbon steels) may be estimated to within $\pm 36°$ C for a given transition curve, assuming the conditions of test were similar to those used in this investigation. This is generally referred to as the confidence interval.

ACKNOWLEDGMENTS

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Finally, the authors are especially grateful to M. L. Hallett for the final calculations.

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6. Hoel, P. G., *Ibid.*, 248.

Appendix I

Schedule A, SAE 1020 Steel

Type notch	*Size*	*E*	*F*	*C*
Keyhole	1/4	−70, −102, −87	−45, −56, −50	−72, −134, −142
"	1/2	−20, −20, −21	−21, −18, −18	−25, −19 −22
"	Full	−16, −18, −2	−18, +5, +5	−15, −21, −12
V	1/4	−26, −24, −32	−24, −24, −24	−27, −26, −24
"	1/2	−1, −10, −13	−9, −9, +14	−10, −12, −12
"	Full	+5, +3, +1	+24, +21, +21	−3, +2, +3
		−453	−226	−571

Type notch	*E*	*F*	*C*	
Keyhole	−356	−216	−462	−1034
V	− 97	− 10	−109	− 216
	−453	−226	−571	−1250

Type notch	1/4	1/2	*Full*	
Keyhole	−758	−184	−92	−1034
V	−231	− 62	+77	− 216
	−989	−246	−15	−1250

Bar size	*E*	*F*	*C*	
1/4	−341	−223	−425	− 989
1/2	− 85	− 61	−100	− 246
Full	− 27	+ 58	− 46	− 15
	−453	−453	−571	−1250

where:
E = Energy transition temperature, ° C.
F = Fracture appearance transition temperature, ° C.
C = Contraction of area under notch transition temperature, ° C.

Schedule B, SAE 1020 Steel, Calculations

Main effects and interactions	
SS_T*	$= 1/54[3(453^2 + 226^2 + 571^2) - 1250^2] = 3416$
SS_N	$= 1/54[2(1034^2 + 216^2) - 1250^2] = 12{,}391$
SS_B	$= 1/54[3(989^2 + 246^2 + 15^2) - 1250^2] = 28{,}779$
SS_{TN}	$= 1/54[6(356^2 + 97^2 + 216^2 + 10^2 + 462^2 + 109^2) - 1250^2] = 16{,}423$
SS_{TN}	$= 16{,}423 - 12{,}391 - 3{,}416 = 616$
SS_{TB}	$= 1/54[9(341^2 + 85^2 + 27^2 + 223^2 + 61^2 + 58^2 + 425^2 + 100^2 + 46^2) - 1250^2] = 33{,}363$
SS_{TB}	$= 33{,}363 - 3{,}416 - 28{,}779 = 1{,}168$
SS_{TNB}	$= 1/54[6(758^2 + 231^2 + 184^2 + 62^2 + 92^2 + 77^2) - 1250^2] = 46{,}622$
SS_{NB}	$= 46{,}622 - 12{,}391 - 28{,}779 = 5{,}452$
SS_{Total}	$= 1/54[54(70^2 + 102^2 + 87^2 + \ldots + 3^2 + 2^2 + 3^2) - 1250^2] = 58{,}987$
$SS_{Residual}$	$= 58{,}987 - 3{,}416 - 12{,}391 - 28{,}779 - 616 - 1{,}168 - 5{,}452 = 7{,}165$

* SS = sum of the squares: T = method of determining transition temperature; N = type notch; B = bar size.

Schedule C, Results of a Statistical Analysis of the Impact Transition Temperature of Hot Rolled and Normalized SAE 1020 Steels*

Source variation	*DF*†	*SS*	*MS*	*F*	*Significant levels*‡ 5%	1%
T	2	3,416	1,708	9.54	3.34	5.45
N	1	12,391	12,391	69.22	4.20	7.64
B	2	28,779	14,390	80.39	3.34	5.45
TN Interaction	2	616	308	1.72	3.34	5.45
TB Interaction	4	1,168	292	1.63	2.71	4.07
NB Interaction	2	5,452	2,726	15.22	3.34	5.45
Residual	40	7,165	179			
	53	58,987	1,113			

Notes for Schedule C

* For the calculations see Schedule B.
† T = method of determining transition temperature; N = type notch; B = bar size; DF = degrees of freedom; SS = sum of the squares; MS = (SS/DF) = mean square; F = $(MS/\text{residual } MS)$ = F value or the ratio of two mean squares.
‡ Taken from Hoel.[5]

Gas Flow Requirements for Inert-Gas-Shielded Arc Welding

Factors which determine the flow of inert gases required for gas coverage and methods used of measuring same

by Glenn J. Gibson

INTRODUCTION

EACH of our fusion-welding processes is characterized not only by the source of heat, but by the method of protection of the molten metal from the atmosphere. In gas welding, the burning gases act as a partial protection, but for many metals, some flux must also be used. Welds made by the metal-arc process receive protection from the electrode coating. In submerged-arc welding the arc is literally smothered in flux. Gas-shielded arc welding receives its protection from an envelope of inert shielding gas that flows from a nozzle surrounding the electrode.

It is seldom that anybody uses more gas welding flux than is necessary. Electrode manufacturers carefully control the amount of flux extruded on the rod. In submerged arc welding the unfused flux is carefully picked up with a vacuum cleaner. Unfortunately there are no similar self-limiting factors in the control of gas shielding. Helium and argon are invisible and the only evidence of waste is empty cylinders. There is automatic flow control equipment available to prevent the obvious waste of gas when the electrode holder is not being used. The primary question is: How much gas is required to produce an acceptable weld? It is obviously impossible to prescribe specific flows for the large variety of present applications, and many factors affect the flow of gas required for each application. The purpose of this paper is to demonstrate some of these factors and to establish principles to guide the judgment of those concerned with using their shielding gas in the most efficient manner. There are, necessarily, many limitations to an investigation of this nature. The tests to measure the factors affecting gas flow were made with tungsten-arc welding equipment. One representative electrode holder was used with two sizes of gas nozzles. It is quite possible that the results obtained with other equipment would be somewhat different. However, in an investigation of this type, small comparisons are ignored in order to establish broad principles. The tests employed were not practical welding applications, but were such that the extent of gas protection could be measured.

Gas flow rates are generally established by the appearance of welds. Not much attention is usually paid to establishing conditions which require less gas for adequate shielding or gas coverage. The use of excessive gas flows can be due to many reasons. One of the most common is to use a little more, to be on the safe side. This is valid reasoning provided that the "little more" did not start from somewhere well on the safe side. In manual welding, operators tend to use excessive gas flows to allow for their own carelessness in occasionally drawing out excessive arc lengths.

Before getting into the subject matter of this report, it is well to consider some definitions. The most important new term used in this discussion is "gas coverage." *This term is used to designate the area on the surface of the workpiece from which air is excluded by the shielding gas.* The measurements of this area and the factors which affect it, constitute the subject matter of this investigation. In other words, we are concerned with how much gas coverage you get—not how much is needed. The gas coverage required for each job depends on the properties and the thickness of the material being welded, the current value, welding speed and the use of jigs and fixtures.

The scope of this investigation is thus limited to demonstrating gas coverage for a range of gas flows and various controllable operating factors. The principal operating factors investigated were: type of shielding gas, gas nozzle diameter, nozzle-to-work distance, and air currents.

TEST METHODS

In spite of the limited number of variables investigated the number of tests becomes very large when a range of gas flows is employed for each conbination of conditions. The total number of individual tests made in this investigation was approximately 720. Obviously a test was required that was quick and easy to measure. The basic quantitative test employed was a spot test. In this test the electrode holder is positioned above the workpiece and held stationary. The extent to which the gas stream from the holder excluded the air from the surface of the workpiece under the holder was measured by two different methods.

Aluminum Spot Test

One spot test employed an a-c high-frequency stabilized arc between the electrode and an aluminum workpiece. The current value, arc time and thickness of the aluminum were fixed so that the melted spot was about $^{3}/_{16}$ in. in diam and the gas coverage was indicated by the diameter of the arc-sputtered zone.[1] The current value was 150 amp, time 30 sec, arc length $^{3}/_{32}$ in. and the aluminum plate was $^{1}/_{8}$ in. thick. A series of test patterns in Fig. 1 show definite boundaries of the arc-sputtered zone which can be readily measured.

The sensitivity of the test was measured by mixing various amounts of air into the shielding gas. The effect of the air is shown in Fig. 2. Increasing air mixed with the shielding gas gradually reduces the size of the arc-sputtered zone until at about 0.10% air the zone is completely absent. The sensitivity of this test is such that the effect of 0.02% air in the shielding gas is obvious. This test demonstrates

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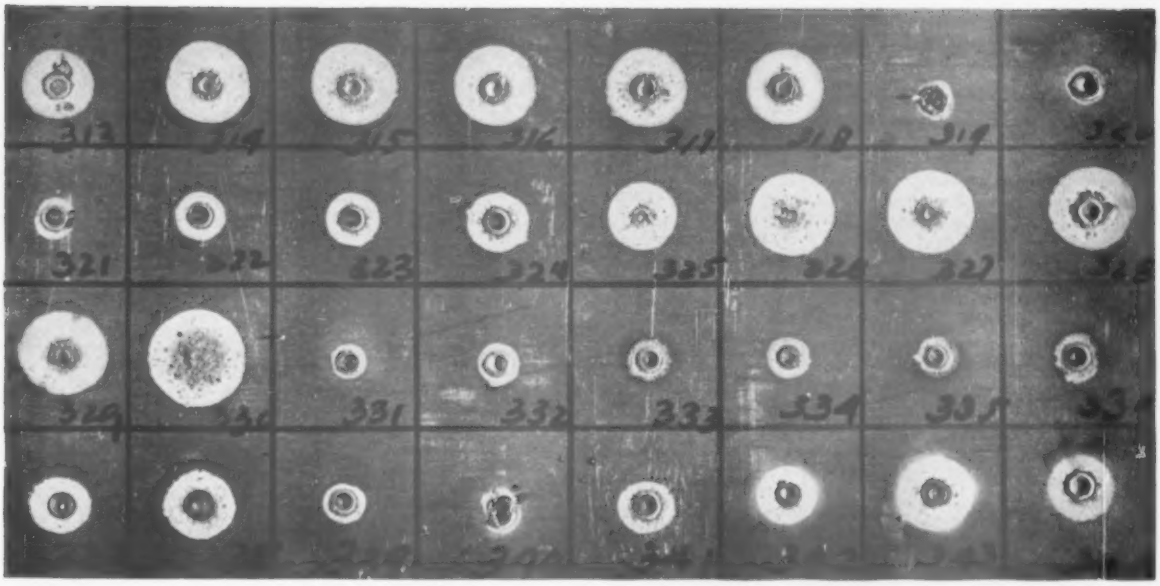


Fig. 1 Typical aluminum spot test patterns of gas coverage

the high purity of argon required for welding aluminum. Even small leaks in the gas line or holder could aspirate enough air into the shielding gas to lose this cleaning action.

This aluminum spot test has two serious limitations. It cannot be used with pure helium because of the very small amount of cleaning action associated with the combination of helium and an a-c high-frequency power supply. However, when 20% argon is mixed with helium the cleaning action is comparable to that of pure argon. The second limitation is the uncertainty of the cleaning action extending to the boundary of the complete gas coverage. Arc length apparently has some effect on varying the arc-sputtered zone under the same shielding conditions but this factor was held constant. The electrode size was also fixed at $^{3}/_{32}$ in. diameter.

Titanium Spot Test

A second type of spot test used to measure gas coverage was the titanium spot test. This consisted of maintaining a low-current d-c arc for a fixed time on a 16-gage titanium sheet. The pattern covered by the stream of shielding gas is outlined by the oxidization caused by the heat of the arc. In Fig. 3 are photographs of titanium spot tests just before and just after the arc was broken. The white hot metal can be seen directly under the electrode. The patterns are already formed and are retained as the metal cools. This photograph also shows the two gas nozzles used in this investigation. On the left is the $^{5}/_{8}$-in. inside diam nozzle which is simply a straight section of glass tubing, and on the right is the $^{3}/_{8}$-in. nozzle which is a tapered section of glass tubing.

The current and time were controlled so that a spot about $1^{1}/_{4}$ in. was heated to the temperature at which the metal oxidized in air. The time was fixed at 20 sec which was sufficient for the heat from the arc to progress outward the desired amount. The current value for argon shielding was 50 amp, and 30 amp was used for helium. These currents resulted in a molten spot about $^{3}/_{8}$ in. in diameter, but the surface tension of the titanium was sufficient to prevent the molten metal from dropping out. A few representative spots with both argon and helium shielding are shown in

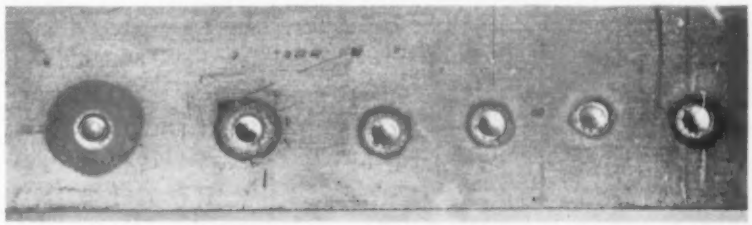


Fig. 2 Effect of air mixed with argon on the appearance of aluminum spot tests

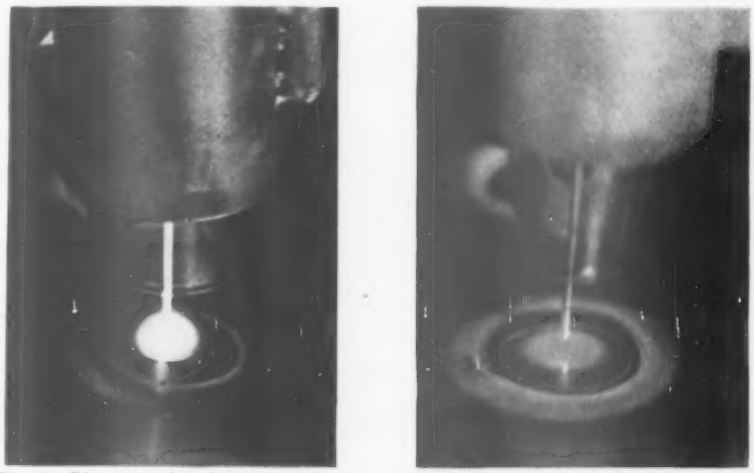
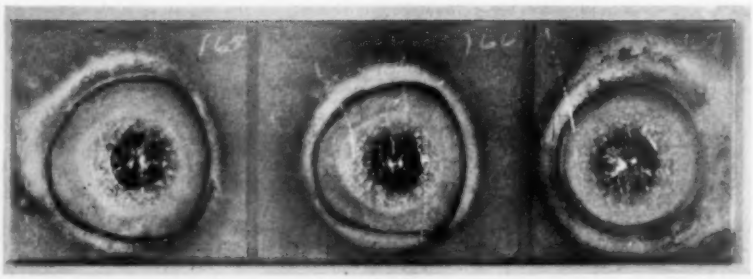
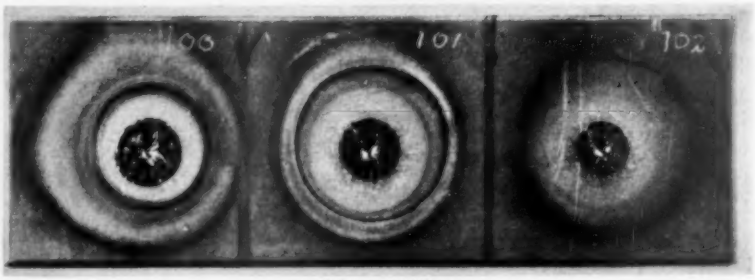


Fig. 3 Photographs of titanium spot tests just before and just after the arc was broken

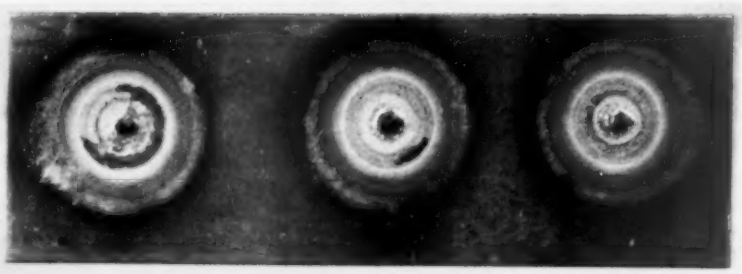
Fig. 4 Appearance of typical titanium spot test



Argon shielding



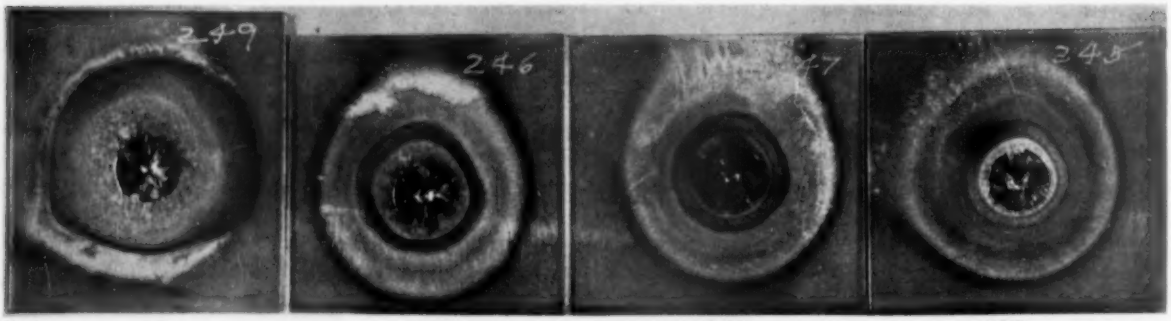
Helium shielding



Underside of spots

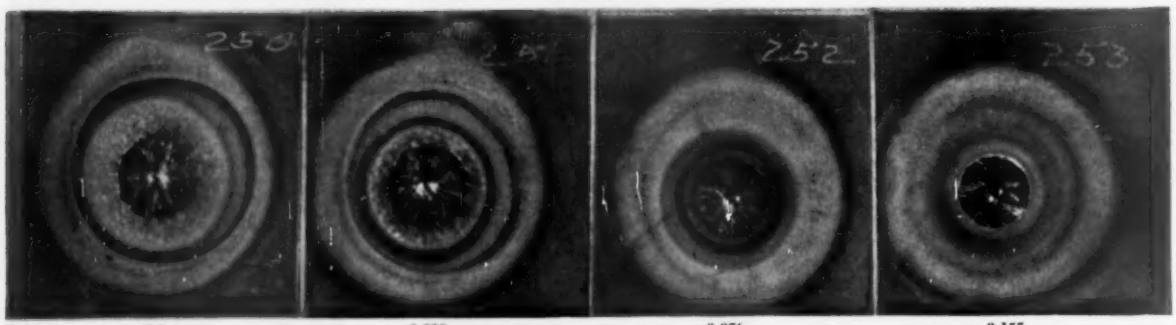
Fig. 4. Some judgment was necessary in measuring the size of the pattern but the general rule was to measure the smallest diameter bounded by dark temper color lines. In making these tests it is necessary to maintain the gas flow until the titanium cools below about 800° F in order to preserve the gas patterns. At low gas flows it was found necessary to increase the flow just before the arc was broken in order not to lose the pattern created by the thermal expansion of the gas shield from the heat of the arc.

The sensitivity of the titanium spot test was measured by adding small amounts of air to the shielding gas and observing the effect on the shielded area of the surface. A condition was chosen in which argon and helium produced about the same gas coverage at the same flow. This was with a $^{5}/_{8}$-in. diam nozzle, $^{3}/_{16}$-in. nozzle-to-work distance and a gas flow of 32 cfh. The results of these tests are shown in Fig. 5. Air mixtures as low as 0.030–0.040% show an effect in producing an amber temper color on the shielded portion. As air is increased in the mixture the patterns become smaller in size until only the molten spot is free from heavy oxidation. This molten spot at the center probably absorbed more oxygen than the cooler portions, which resulted in less surface oxidation. The metallurgical effect of this air on the titanium was not investi-



% Air 0.0 0.042 0.086 0.145

Argon-air mixture



% Air 0.0 0.030 0.076 0.155

Helium-air mixture

Fig. 5 Effect of air mixed with shielding gas on the appearance of titanium spot test

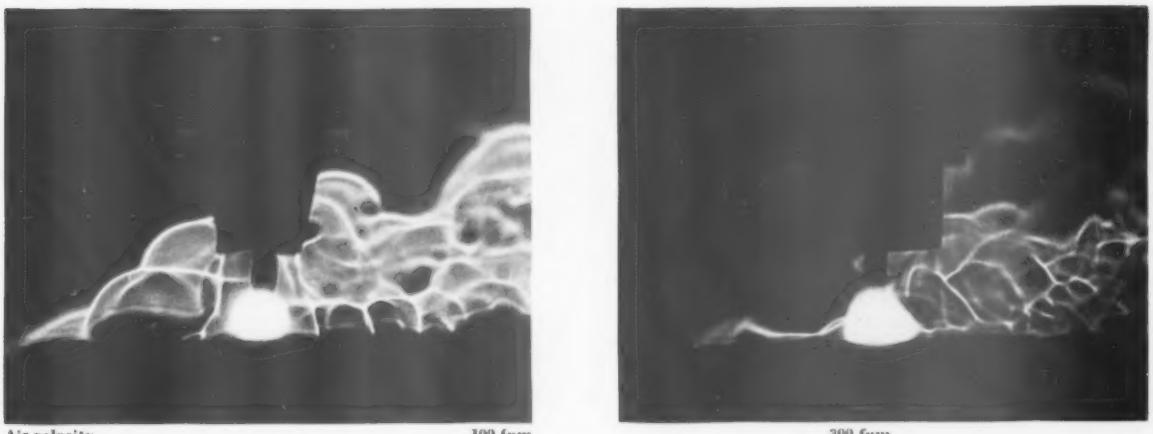
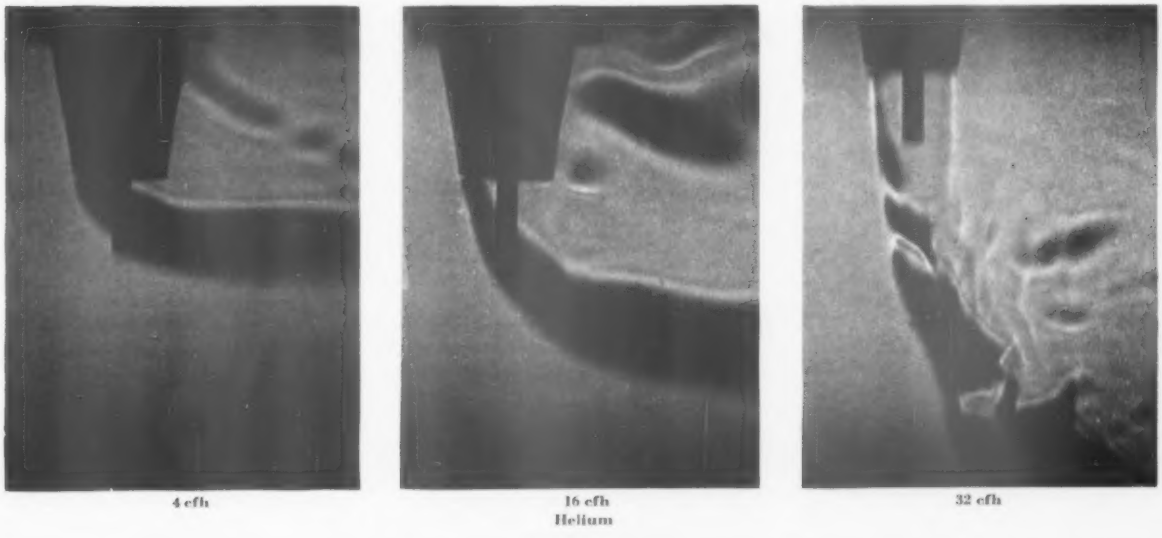


Fig. 6 Schlieren photographs of good gas coverage (left) and insufficient coverage with 80–20 helium-argon mixture



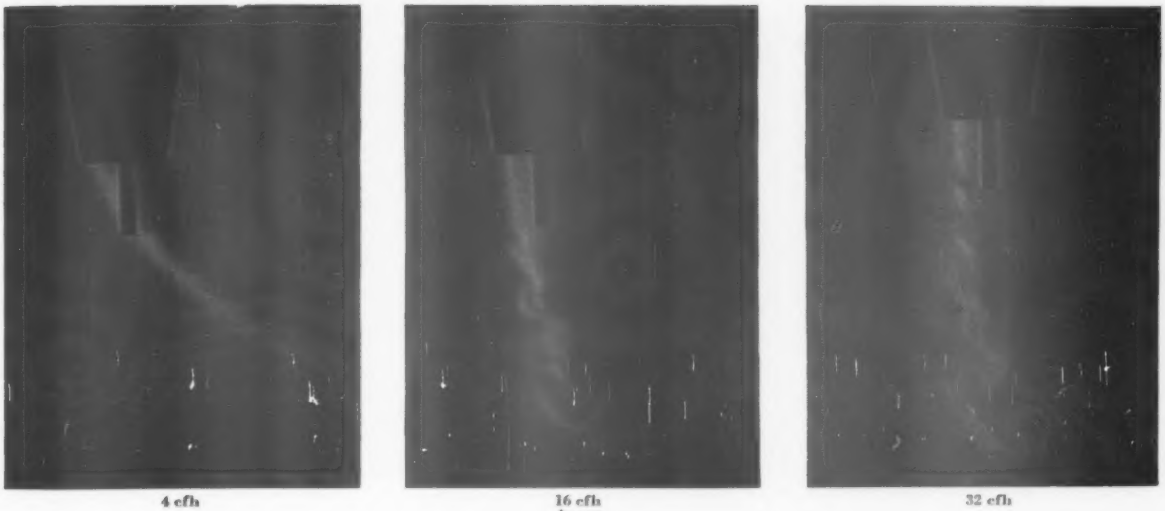


Fig. 7 Schlieren photographs showing deflections of shielding gas streams in a 100 fpm air current with laminar and turbulent flow conditions

gated. The test is very sensitive and the limits of gas shielding are well defined. The one significant limitation of the method was that the effect of current magnitude could not be evaluated.

The Schlieren Method

The third method employed to investigate gas coverage was by schlieren analysis. This optical method for making the gas visible was described in a previous paper;[4] however, a brief description of the principles is worth repeating to aid in the interpretation of schlieren photographs. All geometric objects such as the gas nozzle show up in profile. Gases are indicated as a composite of shaded light and dark areas. These light and dark areas are caused by differences in index of refraction of the gases within the disturbance. These refraction changes are due to variations in density as a result of the presence of another gas in the ambient air or of differences in temperature or pressure. A greater difference in density results in a sharper image or boundary on the photograph, thus helium shows more readily than argon.

Schlieren photographs of arcs are complicated by the heating of both the gas and the workpiece which in turn heat the air, making it visible. The effect of the shielding gas rebounding from the workpiece or rising because of being lighter than air further confuses the interpretation of the results. However, if the subject is placed in a gentle air current, the rising and rebound gas will be carried off and the flow conditions about the nozzle can be more readily observed. Schlieren photographs were taken to illustrate the general nature of gas coverage, free flows in various air currents, and the effects of various joint forms.

Air Current Tests

The major part of the investigation was made in relatively still air; but since air drafts are often troublesome in the practice of inert-gas-shielded arc welding, tests of gas coverage in air currents were made with both the aluminum and titanium spot tests and with the schlieren apparatus. The air currents were produced with an ordinary 12-in. ventilating fan fitted into a 13-in. diam by 3-ft cylindrical wind tunnel. The air flow was regulated with a variable voltage transformer and measured with an Alnor velometer. The tunnel was fitted with a cheesecloth baffle to equalize the velocity distribution so that a fairly steady reading could be obtained with the velometer. The testing was done about 6 to 10 in. from the end of the tunnel which was sloped downward about 15 deg for the spot tests on flat horizontal sheets in order to maintain the velocity as close to the surface as possible. The introduction of air currents made it im-

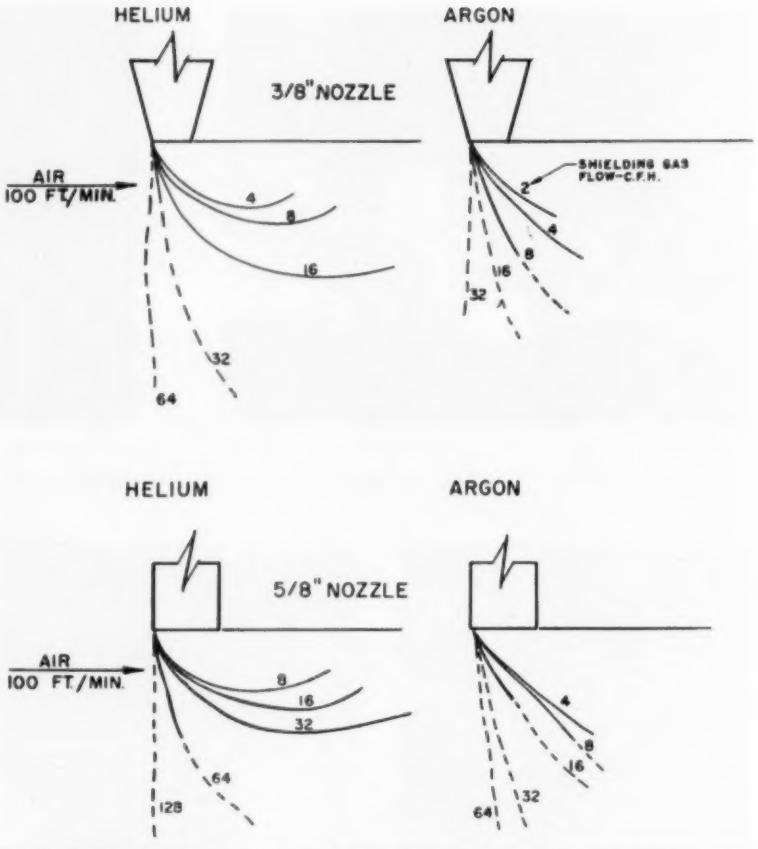


Fig. 8 Deflection of various shielding gas streams in an air current (direct tracing from Schlieren photographs)

Note: Solid lines indicate laminar flow. Broken lines indicate turbulence.

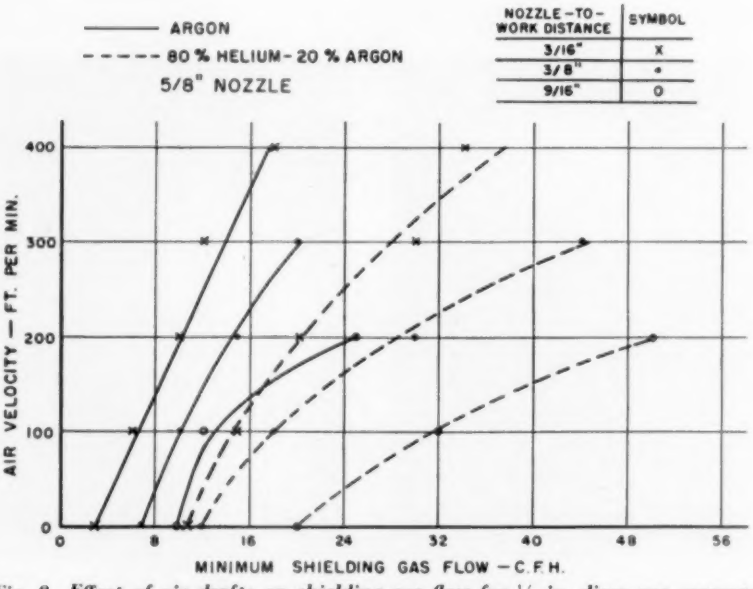


Fig. 9 Effect of air drafts on shielding gas flow for $^1/_2$-in. diam gas coverage with the aluminum spot test

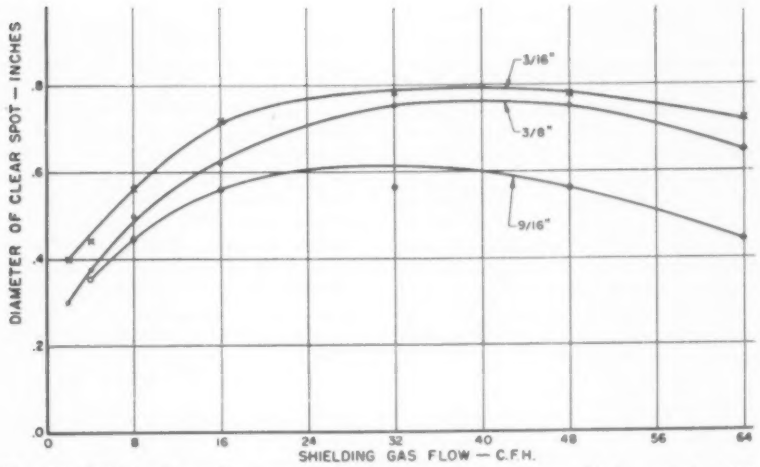


Fig. 10 Effect of nozzle-to-work-distance on gas coverage, 3/8-in. nozzle with argon

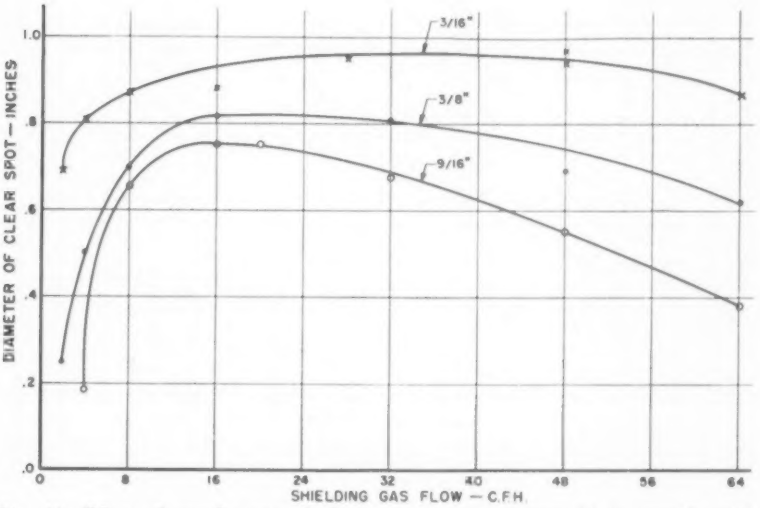


Fig. 11 Effect of nozzle-to-work-distance on gas coverage, 1/8-in. nozzle with argon

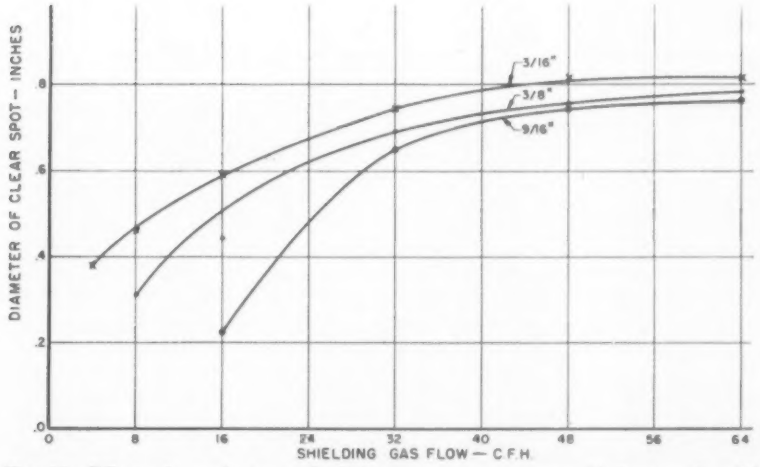


Fig. 12 Effect of nozzle-to-work-distance on gas coverage, 2/8-in. nozzle with helium

practical to investigate the effect of various flows in terms of the size of the spot produced. The gas flows were therefore adjusted to the minimum rate at which an average 1/2-in. diam spot could be maintained. In spite of the relatively crude methods employed the minimum flow rates required were quite well defined.

DISCUSSION OF RESULTS

Schlieren Analysis

The schlieren method could not be used for quantitative measurement of gas coverage except for special conditions. A previous paper[2] describing the schlieren method was limited to a qualitative study of helium and argon shielding. The tests were only of still air conditions and the true gas coverage was obscured by the gases rebounding from the plate. A schlieren photograph that does closely indicate the extent of the completely protected area on the surface of the plate is shown in Fig. 6. Both adequate and insufficient gas coverage of an a-c arc on an aluminum plate are shown. These were made in air currents which carried away the rebounding gas so that the shielding stream of helium is fairly well defined. The spot under the arc on the left-hand photograph has a circular clean arc-sputtered zone while that of the right photograph showed none. The use of two types of nozzles to illustrate good and poor coverage should not be taken as a reflection on their relative merits. The comparative effect of the two nozzles is shown in the spot test data. The schlieren method shows the stream of shielding gas only under limited conditions of use and could not be employed for any quantitative investigations. It is, however, very helpful in simply making the gases visible. The left-hand photograph in Fig. 6 shows the expansion of the gas stream after leaving the nozzle thus demonstrating that the extent of gas coverage can be larger than the nozzle orifice.

Schlieren studies of free flow conditions are more valuable than those with an arc. The effect of an air current on the flow of shielding gas from a gas nozzle pointed vertically downward in shown in Fig. 7. The nozzle shown has an orifice diameter of 3/8 in. and the 2/32-in. diam electrode protrudes 3/4 in. from the nozzle. Helium offers less resistance to displacement by the air because the kinetic energy of the helium stream is less than that of argon and because of its normal tendency to rise. This would indicate that helium would require comparatively higher gas flows than argon to weld successfully in a draft or wind. However, the most important characteristic shown is the contour of the windward edge of the gas streams. Helium at 4 and 16 cfh has a smooth surface indicating laminar flow. Even at 32 cfh the edge is smooth for about 3/4 in. from the nozzle whereas only the 4 cfh

flow of argon is laminar. The wavy edges show turbulence and the entrainment of air toward the center of the stream. These effects will be related to the gas coverage shown in the titanium spot tests.

A more complete series of such tests with both $^3/_4$- and $^5/_8$-in. diam nozzles is shown in Fig. 8. These are tracings of schlieren photographs which are superimposed to show the effect of variations in gas flow in a current of air. A flow of about 4 cfh of gas has an exit velocity at the $^5/_8$-in. nozzle equal to the 100 fpm air current. Similarly, a flow of 12.5 cfh through the $^5/_8$-in. nozzle is at a 100 fpm velocity.

At this point it might be well to examine the factors which affect the nature of the gas flow. The geometry of the electrode holder is significant for the maximum laminar flows. The length of the unsupported electrode has a direct effect on this maximum velocity. However, this also affects the minimum usable length of electrode so the design of a holder is a compromise. The one holder used in this investigation was the Airco® Heliweld machine holder with a water-cooled gas nozzle. The length of electrode from the collet to the gas nozzle with this holder is $1^1/_2$ in. The maximum flow at which a gas stream loses its laminarity and turns turbulent is an inverse function of its density-viscosity ratio. This ratio for helium is about one-eighth that of argon. A rough comparison of the flow or velocities of argon and helium in Fig. 8 for similar degrees of turbulence is about one to four.

Aluminum Spot Tests

The aluminum spot test has a limited usefulness in measuring gas coverage and its principal value is in its simplicity and sensitivity. Its limitations lie in the uncertainty that the arc sputtering extends over the full area of gas coverage. However, since the sensitivity test shows that the arc sputtering does not extend beyond the gas coverage containing more than about 0.04% air, it could be used to measure coverage which was known to be within the arc-sputtered range of the arc conditions used in the test. Spot sizes up to $^3/_4$ in. diam were obtained under various flow conditions. Therefore this method is satisfactory for determining the minimum gas flows required to obtain a spot $^1/_2$ in. in diameter.

Most of the experimental work done with the a-c aluminum spot tests was in air drafts. The results are shown in Fig. 9. In this chart the velocity of the air at the nozzle was plotted against the minimum shielding gas flow required to produce an arc-sputtered spot of about $^1/_2$ in. diameter. Other variables investigated were nozzle-to-work distance and shielding gas. Several spot tests were required to obtain each point of the six curves in order to obtain a comparative gas coverage condition.

Several effects are apparent from an examination of Fig. 9. As the air velocity is increased more gas is required. The distance of the nozzle from the work is even more significant in air currents than in still air, and at high velocities it is impossible to obtain a gas shield when the nozzle is more than $^2/_8$ in. from the work. The lower resistance of the helium mixture to being blown away is shown by the flatter shape of the helium compared to the argon curves. Even in still air this test indicated that the flow of the 80% helium – 20% argon mixtures is two times that required for pure argon. The rapid increase in the gas flow requirements with air velocities obviously shows the advisability of eliminating drafts. Even though the minimum flow rates for argon are much less than those of the mixture or of pure helium, the choice of the gas should be based on the desired arc characteristics and the total cost per foot of weld. The use of helium generally permits greater welding speeds which introduces the labor factor in the final weld cost.

In the application of the process it is not necessary to go looking for drafts with a velometer, nor is it necessary to have the air so still that smoke will rise vertically. A draft of 100 fpm velocity is barely dis-

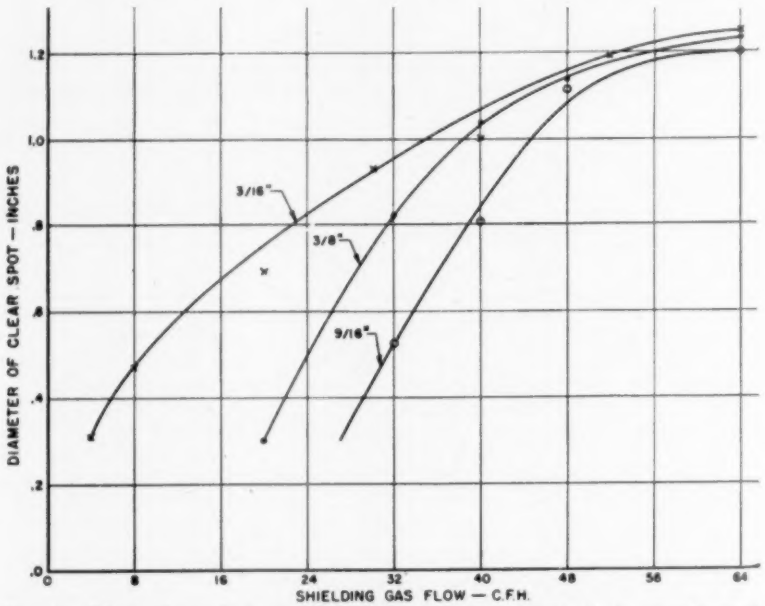


Fig. 13 Effect of nozzle-to-work-distance on gas coverage, $^5/_8$-in. nozzle with helium

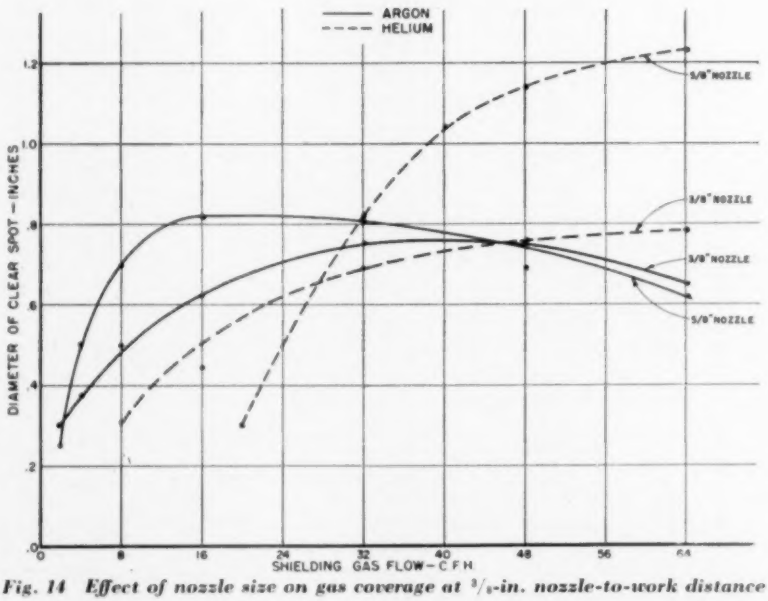


Fig. 14 Effect of nozzle size on gas coverage at $^3/_8$-in. nozzle-to-work distance

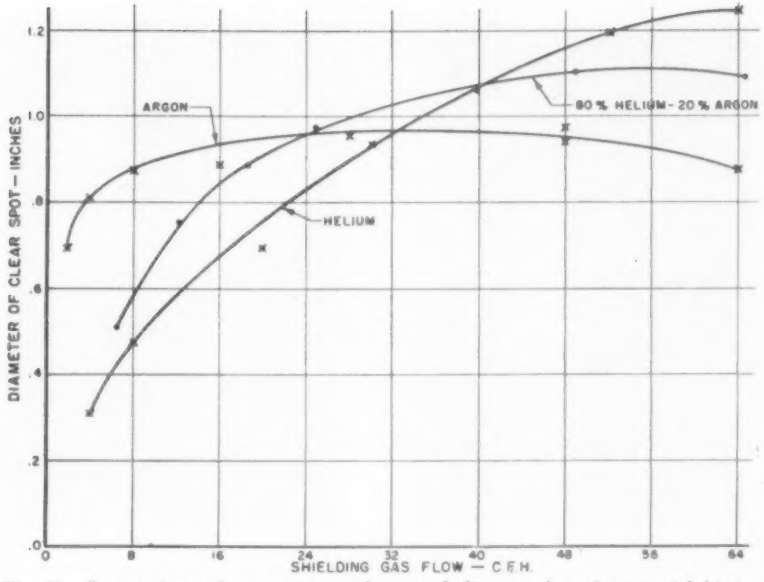


Fig. 15 Comparison of gas coverage of argon, helium and a mixture with $^5/_8$-in. nozzle at $^3/_{16}$-in. nozzle to work distance

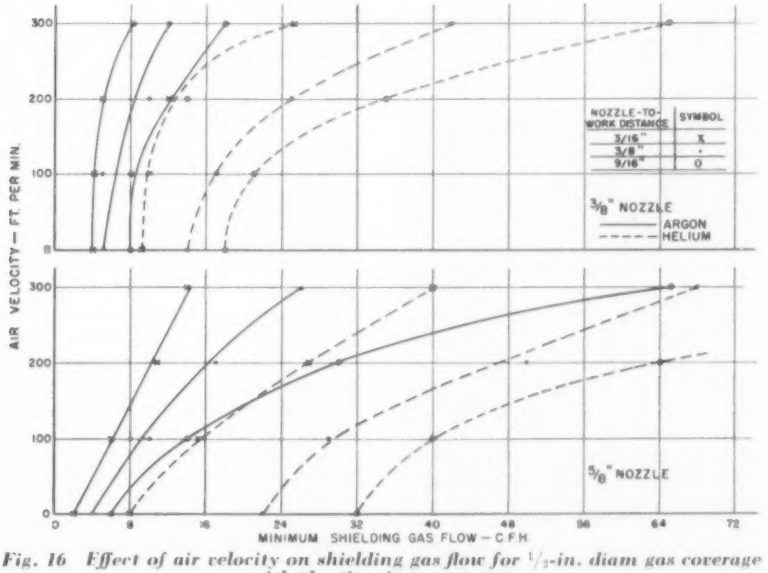


Fig. 16 Effect of air velocity on shielding gas flow for $^1/_2$-in. diam gas coverage with the titanium spot test

cernible, but it can be definitely sensed on moist skin and Fig. 9 indicates that 100 fpm is a good practical limit for drafts. Welding being done in drafts than can be definitely felt should be protected.

These draft tests may also be used to evaluate the effect of welding speed on gas coverage. High welding speeds for this process are normally about 100 ipm rather than 100 fpm which was the lowest air current measured. Gas coverage effects from high welding speed are, therefore, considered negligible from the standpoint of relative motion. The high currents and long molten pools associated with high welding speeds are dominant factors in gas shielding.

Titanium Spot Tests

The titanium spot test is effective in showing the extent of gas coverage. The test results were consistent and could be readily plotted. The nature of the test is such that it is equally effective for helium argon, or mixtures of both, and it is independent of arc characteristics and arc length. The gas flow range studied was from the very minimum up to 64 cfh which in most cases was several times in excess of that required.

The relation between the gas flow and the diameter of the spot effectively covered is shown for a series of variables. The chart in Fig. 10 was obtained with argon shielding through a $^3/_8$-in. diam nozzle and with three spacings of the nozzle from the workpiece. The minimum flows that could be used to obtain a smooth arc were very low, from 2 to 4 cfh. As the flow increased, the gas coverage increased until it reached a maximum at 24 to 32 cfh flow. Further increase in gas flow resulted in less area of gas coverage. This can be readily explained by the turbulence of the gas stream and the gradual entrainment of air. The longer length of free flow from the nozzle resulted in greater degree of penetration of air into the gas stream and a smaller area of complete coverage. Close nozzle-to-work conditions provide greater coverage and require less gas flow for a given spot diameter. These curves are very similar to those obtained with the aluminum spot test.

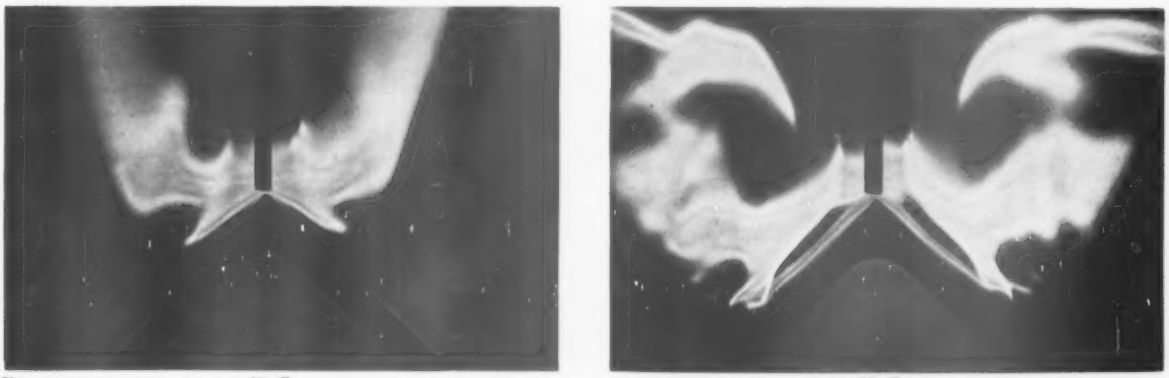
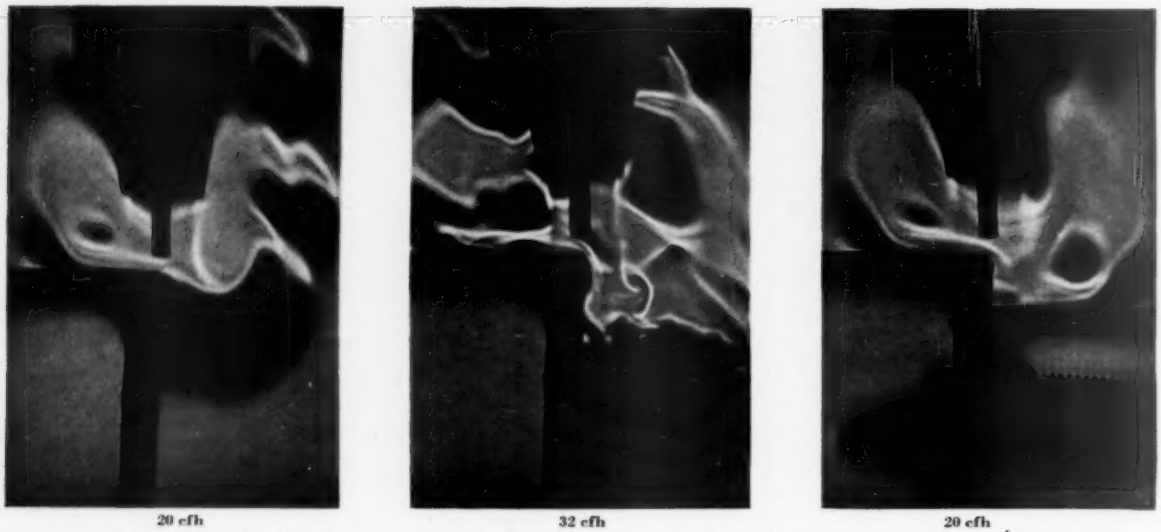


Fig. 17 Schlieren photographs showing the effect of gas flow on gas coverage for flat position corner welds



20 cfh 32 cfh 20 cfh

Fig. 18 Schlieren photographs showing comparative gas coverage for three conditions of horizontal corner welds

The gas coverages obtained with argon using the larger $^{5}/_{8}$-in. diam nozzle are shown in Fig. 11. The increase in size of the coverage is not as great as the increase in diameter of the nozzle. Maximum values of gas coverage are attained at a flow of about 16 cfh which is about at the limit of laminar flow for this nozzle. This flow is considerably less than that of the smaller $^{3}/_{8}$-in. nozzle. The only apparent explanation in differences in behavior of the two nozzles as to the shift in flow rates at the maximum coverage is that the $^{5}/_{8}$-in. nozzle was tapered.

The gas coverage characteristics of helium are distinctly different from those of argon. The effect of nozzle-to-work distance on the spot diameter for various flows are shown in Figs. 12 and 13 for $^{3}/_{8}$- and $^{5}/_{8}$-in. nozzle sizes. The pattern of the curves of the two nozzles is very similar, being widely spread at low flows and converging to a maximum spot diameter at the highest flows. The spread at the low flows is due to the lightness of the helium which requires a definite velocity to be forced downward. More velocity and hence greater flows are required when the workpiece is farther from the nozzle. As this requirement is met, increased flows result in velocities which alleviate this rising effect and the gas coverages become independent of this spacing. Apparently with helium, the effect of turbulence is too slight to cause a decrease in gas coverage within the range of gas flows investigated.

The basic data on gas coverage are shown in the 12 curves of Figs. 10–13. These data may also be plotted in different combinations for comparative purposes. The effect of nozzle size for one nozzle-to-work spacing is shown in Fig. 14. The difference in shape of the two nozzles used and the different effects of helium and argon make it difficult to draw any rules for choice of nozzle size except that the large nozzle provided greater coverage. With helium at high flow rates, the increase in size of the gas coverage is the same as the increase in diameter of the nozzle. However, with manual welding the accessibility of the work and visibility of the arc generally limit the nozzle to $^{3}/_{8}$ or $^{1}/_{2}$ in. diam.

Many significant differences between helium and argon are shown in the data presented. However, it might be well to compare one typical condition on a common chart as shown in Fig. 15. Argon provides the greater coverage at low flows while helium gives the maximum coverage at high flow rates. The coverage of an 80% helium – 20% argon mixture lies almost midway between. This offers a possible economic advantage in the use of the mixtures over pure gases. In investigating cost, cognizance should be taken of arc characteristics of the mixture as to penetration and welding speeds.

The effect of air-currents on gas coverage is shown in Fig. 16. The data are plotted so that the minimum gas flow is shown for a comparable gas coverage. Increased air velocity has much less influence on argon flow requirements than on the helium flow requirements. The smaller nozzle with correspondingly higher gas velocities provides more efficient coverage than the larger one. As the nozzle-to-work spacing is increased gas flow requirements at high air velocities are several times those required for still air conditions.

A comparison of the curves for argon with the $^{3}/_{8}$-in. nozzle with the corresponding curves in Fig. 9 shows remarkable correlation between the titanium and aluminum spot tests. The curves for the helium-argon mixture in Fig. 9 are between those of pure helium and pure argon in Fig. 16.

Effect of Joint Form

All previous tests of gas coverage were made with a vertically positioned electrode holder on a flat horizontal plate. A few tests were made to demonstrate rather than measure the effect of the form of the joint on gas flow requirements. This limited program consisted of taking schlieren photographs without an arc in helium and then duplicating the conditions with the titanium spot test. The spot test was employed to check the coverage indicated by the schlieren method.

The first joint form investigated was that of flat position corner welds as shown in Fig. 17. The object was to investigate what flows were required to bring the gas coverage down along the sloping sides of the joint. It is quite obvious that the 20 cfh helium flow failed to do this but the 32 cfh flow did bring the gas down below the corner. The corresponding titanium spot tests showed gas coverage extending $^{3}/_{16}$ in. from the corner for 20 cfh and $^{3}/_{8}$ in. for 32 cfh. The length of the spot along the axis of the joint was $^{7}/_{16}$ in. for both flows. This shows that there is little spread of coverage beyond the diameter of the nozzle when there is no rebounding of the gas stream. The coverage on a flat plate for these gas flows and nozzle spacing is $^{9}/_{16}$ and $^{11}/_{16}$ in., respectively.

An attempt made to obtain schlieren pictures of a flat fillet joint was unsuccessful because the rebounding gases obscured the flow of gas from the nozzle. The coverage shown by the titanium spot tests was $^{11}/_{16}$-in.-diam round spot for both the 20 and 32 cfh flows. This would indicate that gas flow requirements for fillet welds are less than those for a flat surface. Experience has shown that any form which confines the gas requires less flow and provides better coverage.

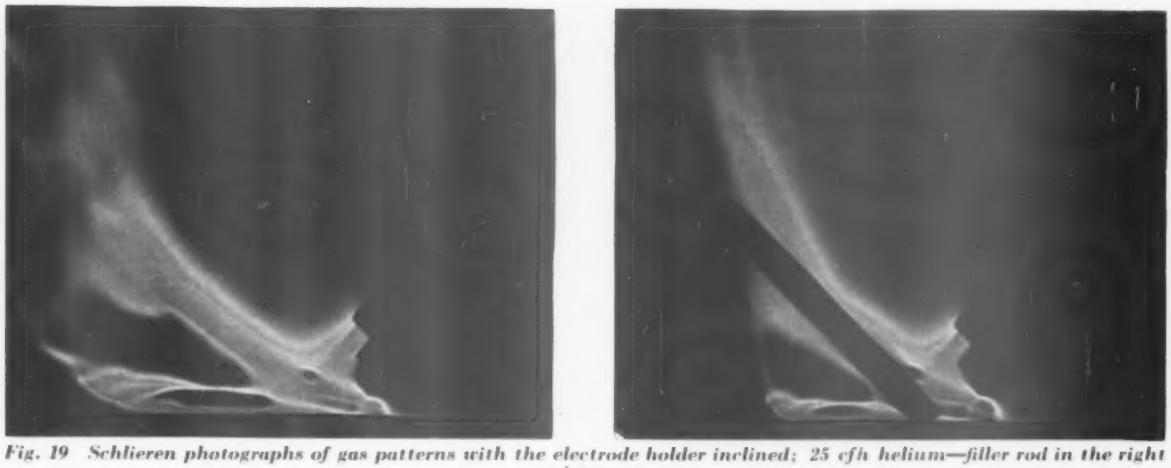


Fig. 19 Schlieren photographs of gas patterns with the electrode holder inclined; 25 cfh helium—filler rod in the right picture

Another joint form in which gas coverage problems are encountered is a horizontal position corner joint. Three comparative conditions of gas coverage on corner joints are shown in Fig. 18. At 20 cfh helium the gas stream curves away from the corner on the open side and provides no protection below this point. Increasing the flow to 32 brings the gas below the corner but it is questionable if all the air is excluded just below the corner. Better gas coverage at 20 cfh is obtained when a baffle is clamped about $^1/_4$ in. below the corner. The effect of this baffle is to make the gas rebound and prevent aspiration of air at the corner. Titanium spot tests with the first two conditions illustrated in the photograph show coverage on the horizontal surface but none below the rounded corner of the weld. The specimen with the baffle indicated coverage down to the baffle.

The effect of inclination of the electrode holder is shown in Fig. 19. The gas is visible on only one side of the nozzle due to the optical effects. The gas coverage is indicated where the solid white area is in contact with the workpiece. The effect of the filler rod in the gas stream is negligible. A titanium spot test could not be conveniently made of this arrangement. The spot test without the filler rod was $^{11}/_{16}$ in. long and $^9/_{16}$ in. wide which corresponds quite closely to that indicated on the schlieren picture.

ARC CHARACTERISTICS OF HELIUM-ARGON MIXTURES

Although this paper is primarily concerned with gas flow rates for gas coverage, the introduction of the effect of mixtures on gas coverage opens the question of the effect of mixtures on welding. It is first necessary to review the arc characteristics of the pure gases in tungsten arc welding. Low current arcs start more readily in argon than in helium, and in argon they are stiffer in that the arc column follows the direction of the electrode which is desirable for low current

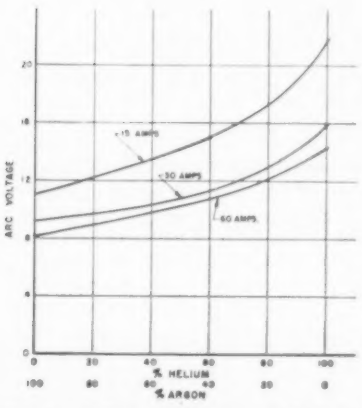


Fig. 20 Effect of mixtures of helium and argon on d-c arc voltage

10 cfh Argon

10 cfh Helium

5cfh Argon + 5 cfh Helium

2 cfh Argon + 8 cfh Helium

Fig. 21 Appearance of low-current d-c arcs in argon, helium and two mixtures

manual welding. The cleaning action of argon on aluminum with alternating current together with its shallow penetration characteristics are also advantageous in the manual welding of thin aluminum. Helium on the other hand has penetration characteristics which make it desirable for manually welding heavy materials, even aluminum. Much higher welding speeds without undercut are possible and the beads are narrow and neat with a minimum amount of heat distortion.

In mixtures of helium and argon the arc characteristics of argon are dominant. This is best shown by the effect of mixtures on arc voltage curves, Fig. 20. Arc voltages obtained with mixtures are all below a straight line connecting the voltages obtained with pure argon and pure helium. Similar results were obtained in a recent fundamental arc investigation.[3] The 80% helium–20% argon mixture has been taken to represent the best combination of characteristics of the two gases for d-c straight polarity tungsten-arc welding.

The ease in arc starting, directional stiffness, and the cleaning action of argon are retained while the arc voltage and penetration properties are increased by ratio of about two to three. Mixtures can therefore be advantageous in increasing welding speeds while retaining the advantages of argon. The directional arc stiffness effect of helium, argon and two mixtures are shown in Fig. 21. The inner white cone of the pure argon arc is greatly diminished in intensity in the arcs of the two mixtures shown, but these arcs did not trail the electrode as in the case of the pure helium arc.

SUMMARY

The object of this investigation has been to obtain information on how to get the most efficient use of shielding gas in inert-gas-shielded arc welding. The inert gases, argon and helium, flow from a nozzle to exclude air from the region around the arc. The extent of exclusion on the surface of the workpiece was measured by aluminum and titanium spot tests. These tests were shown to be sensitive to 0.03% air. Schlieren photographs were taken to show the nature of the gas shield above the workpiece.

The obvious factors affecting gas flow requirements were evaluated and the results are best shown by the various charts. Closer spacing of the nozzle from the workpiece resulted in more extensive gas coverage for a given gas flow. Gas nozzle size has an effect on gas coverage but no definite relationship was determined. Air drafts have pronounced effects on gas flow requirements and should be limited to 100 fpm velocity.

These data also show surprising differences in the behavior of helium and argon in their flow-coverage relationship. The flow rates required for a comparable gas coverage with helium are twice or more than those required with argon. Gas coverage with argon increases with the flow rate up to a maximum and then decreases. Gas coverage with helium continues to increase up to the maximum flow rates used in this investigation. The area of maximum gas coverage obtainable with helium is greater than that obtainable with argon. A mixture of gases consisting of 80% helium and 20% argon has gas flow requirements about midway between those of the pure gases. This mixture when used for d-c straight-polarity tungsten-arc welding, also possesses most of the desirable arc characteristics of both gases.

The practical usefulness of this investigation is limited to serving as a basis for judgment in using shielding gas at maximum effectiveness. Even the choice of shielding gas requires careful consideration. This choice depends on the relative gas cost, arc characteristics and welding speed to obtain the minimum total cost per foot of weld.

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(*Continued from page 171-s*)

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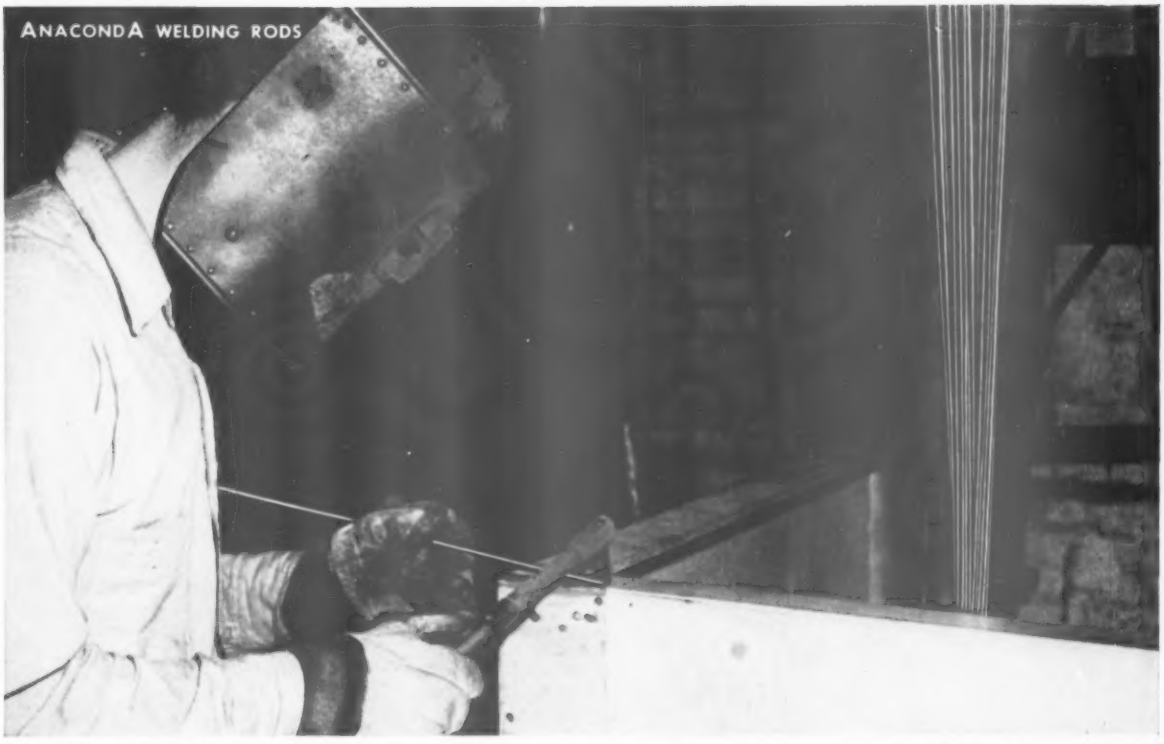
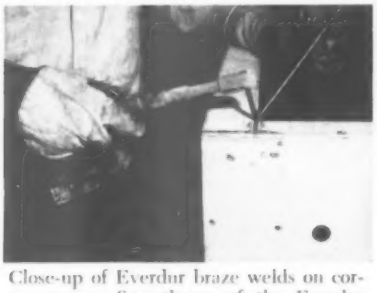


Carbon-arc braze welding of a corner seam with 1/8 in. Everdur Rod on Tyler Fixture Corp. frozen-food cabinet.

Everdur braze welds are used for this meat case scale shelf. The easy-finishing characteristics of joints made with this copper-silicon alloy rod keep costs down.



Close-up of Everdur braze welds on corner seams. Smoothness of the Everdur filler metal is produced by low-melting temperature, free-flowing characteristics.

This Tyler Model TF Frozen-Food Case, ready for shipment, is but one example of how braze-welding with ANACONDA Rods cuts production costs and speeds assembly.

Everdur Rod speeds cabinet production with distortion-free braze welds

Braze welding is an important production operation on these steel frozen-food cases made by The Tyler Fixture Corporation at their Waxahachie, Texas, plant. A total of 8 corner welds, each approximately 3 inches long, is involved.

These braze welds on .0418-in. steel sheet are made with Everdur* Rod, using a carbon-arc without flux—a combination of rod and method that produces a fast and low-cost joint without structural distortions.

The reason Everdur Rod makes these braze welds fast and economically for Tyler—as it is doing for manufacturers everywhere – is the low-temperature-melting and free-flowing characteristics of this copper-silicon alloy rod. It produces a smooth seam that's easy to finish, can't rust and that is dependably strong and uniform.

This is a typical story of Everdur Welding Rod's ability to speed assembly and keep down costs on production operations. The ANACONDA Welding Rod Distributor in your area can tell you the complete story on Everdur and other ANACONDA Copper Alloy Welding Rods. Ask him, or write for your copy of Publication B-13. *The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.*

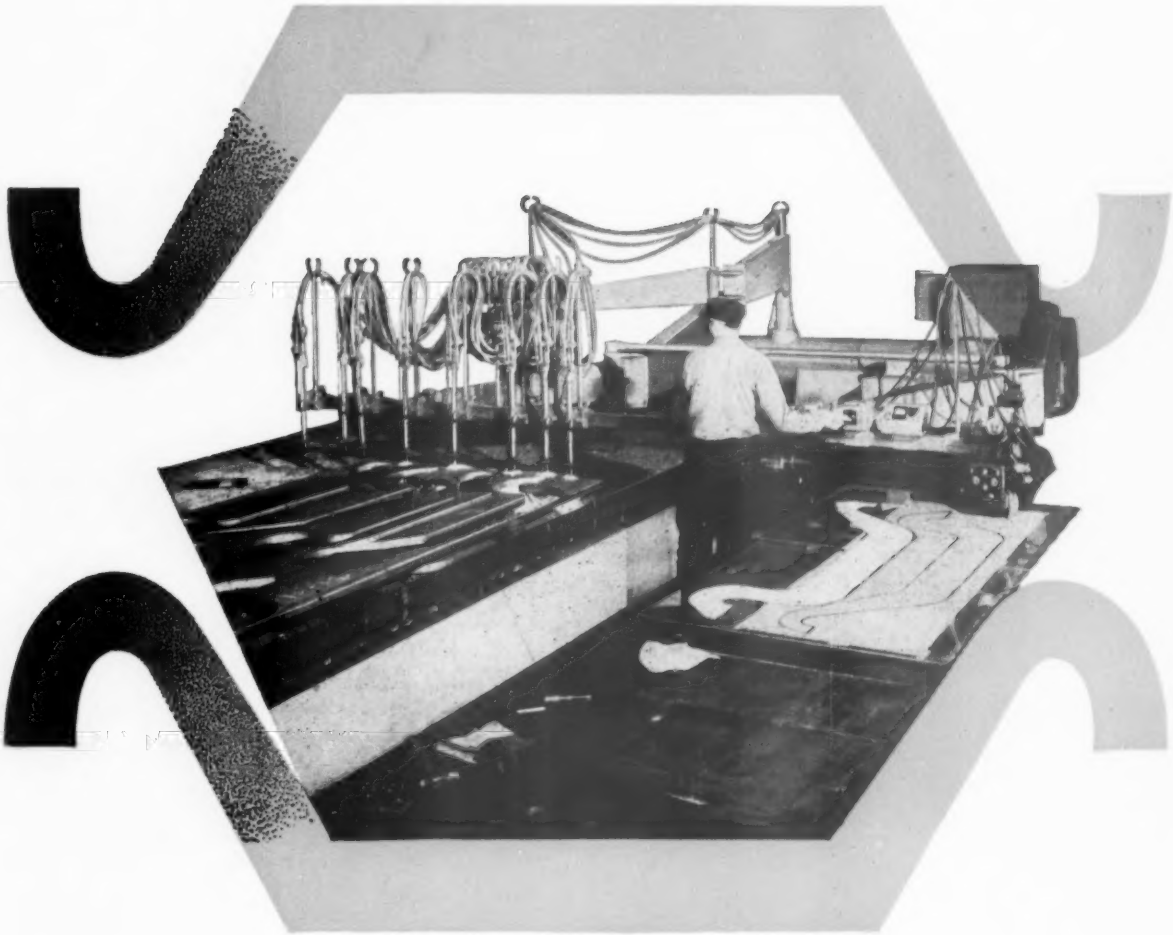
*Reg. U. S. Pat. Off. 53160

braze or weld with confidence

ANACONDA®

welding rods

YOKES FOR AN IRON HORSE...



THE AIRCO NO. 50 TRAVOGRAPH mass produces yoke-shaped equalizer bars for diesel locomotives... to a 1/16" tolerance! Torches are automatically guided by an electronic tracer following a low-cost, pen-and-ink drawing... as four bars are cut simultaneously from 1½" mild steel, hot rolled plate. The versatile Travograph may be used for straight cutting, beveling or squaring... for circles up to 12 feet in diameter... or for straight lines of any desired length by adding extra sections of rail. Intricate shapes... cut to specification... with precision!

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